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DESTRUCTION OF SUBMERGED AQUATIC PLANTS BY 2,4-D[1]

Shelby D. Gerking

Department of Zoology, Indiana University

Submerged aquatic vegetation sometimes becomes so abundant in lakes and ponds during the summer that the recreational value of these waters is seriously impaired. Fishing is difficult because lines and hooks become tangled in the plants and hooked fish often escape by fouling the line. Swimming and boating are also hampered when submerged aquatics "take over" a lake or pond. In pond fish culture dense aquatic vegetation is a real hindrance to general operations, especially when fish need to be removed by draining the pond. Small fish and also larger ones are held back by the vegetation and a considerable loss of usable fish results.

The use of the herbicide, 2,4 dichlorophenoxyacetic acid (2,4-D), has achieved startling results in controlling obnoxious land plants (Tukey, 1947) and emergent aquatic vegetation (Bauman, 1947), so this chemical was considered likely to affect submerged aquatic plants as well. Since 2,4-D is soluble in water, test plants could be treated by dissolving known amounts of 2,4-D in aquaria. Many species usually contribute to a heavy aquatic plant growth in lakes and ponds but experiments were conducted on only four: *Anacharis canadensis*, *Anacharis densa*, *Vallisneria spiralis*, and *Myriophyllum* sp. It was not possible to identify the species of *Myriophyllum* because no flowers or fruits were borne during the observational period. *A. canadensis* was collected in a nearby lake in November and grown in the laboratory for two months. The plants were fragmented in the lake at the time of collection but grew very well in the laboratory. The

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other plants had been growing in laboratory aquaria for some time.

These four species were selected for study because they grew well in aquaria and presented a variety of morphological types. *Anacharis* has a main stem from which whorls of leaves are borne and is fixed to the soil by adventitious roots. *Vallisneria* has a definite root system, bearing leaves singly from a much reduced stem. *Myriophyllum* resembles *Anacharis* in habit but has finely dissected leaves. All of the plants grow completely submerged in the water. If 2,4-D killed plants of these diverse forms, then it is likely that other submerged aquatics would be affected as well.

Various amounts of 2,4-D (see Table 1) were dissolved in six, small aquaria containing dense growths of the test plants. Three aquaria held both species of *Anacharis* and three held *Vallisneria*. Due to a shortage of aquaria the control plants were all planted together in a large tank and placed with the experimental aquaria. The experiments were conducted in the winter. The water temperature taken at 8 A.M. for nine days, varied between 19.2°C. and 22.9°C., and this probably represents the temperature fluctuation throughout the experimental period. The aquaria were placed on a table near a south window where direct sunlight could reach them throughout the day; no additional illumination was used. Each day or so the aquaria were filled to the original water level to replace the loss by evaporation.

TABLE 1.—EXPERIMENTAL SET-UP TO TEST THE EFFECTS OF 2,4-D ON SUBMERGED AQUATIC PLANTS

Aquarium no.	Test plant	Aquarium volume	2,4-D added	Approx. conc.
		l.	mg.	ppm.
1	*Anacharis*	4.46	4.8	1
2	*Anacharis*	4.67	50.9	10
3	*Anacharis*	5.96	594.7	100
4	*Vallisneria*	6.61	7.0	1
5	*Vallisneria*	5.84	56.4	10
6	*Vallisneria*	5.64	563.2	100

EXPERIMENTS WITH ANACHARIS

Distinct changes developed in *Anacharis* plants after 8 days in a concentration of 100 ppm 2,4-D. Dead (yellowish) areas ringed with a black pigment were distributed at random over each *A. canadensis* leaf while the remainder of the leaves and the stem were green. On the thirteenth day of the experiment blackened leaf nodes were noticed on these plants and they fragmented easily. Fragmentation had progressed very far by the seventeenth day when leaves and stems were scattered over the bottom of the aquarium. A few rooted stems had leaves which were yellow and dropping off, but the leaves of these plants had no black rings or blackened leaf nodes. *A. densa* plants reacted very differently in the same concentration of the chemical. No blackened leaf nodes or black bordered dead areas on the leaves ever appeared; instead the leaves and stems gradually lost their green color and became yellow. In this condition the plants fragmented very easily. The experiment was discontinued after 30 days when most of the plants had disintegrated and the whole mass was in an obvious state of decay. Roots of both species were examined at this time and found to be dead (blackened).

The leaves of *A. canadensis* in 10 ppm 2,4-D exhibited the irregular

black rings and the blackened leaf nodes but the blackened tissue did not develop so fast as in 100 ppm. The blackened leaf nodes were actually more common in 10 ppm than in the higher concentration. Fragmentation progressed very slowly and after two months many stems were still erect even though the leaf nodes were blackened and the leaves were covered with black rings. Parts of the leaves and stems were still green, however, enabling the plants to barely survive. *A. densa* plants bleached to a yellow color as they did in 100 ppm but the response was much slower and less pronounced. In natural waters both species would undoubtedly have been destroyed by wave action.

Anacharis plants were affected very little by 1 ppm 2,4-D. The leaves and stems remained green for two months, adventitious roots grew well, and the plants appeared healthy over the entire period. At any given time after the plants had been placed in 2,4-D, a simple test of strength showed that the stems of plants in 100 ppm and 10 ppm were much more fragile than those in 1 ppm. The black rings appeared on a few leaves but doubtless the plants would live indefinitely in this concentration.

Throughout the experiments the control plants showed no change from their normal healthy state.

Microscopical examination of *A. canadensis* leaves which had blackened areas revealed that in reality these were areas of dead tissue (yellowish) surrounded by a ring of blackened cells. There were also areas which were dead and had no surrounding group of blackened cells. A sketch of a typical affected leaf is shown in figure 1. No cyclosis could be observed in either the yellow or the black cells. The blackened leaf nodes of *A. canadensis* were also examined and showed that the epidermal cells had been destroyed and eroded away, exposing the internal structure. This explains the weakness of the stems and why they fragmented so easily.

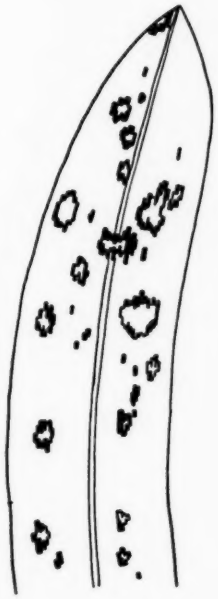

FIG. 1.—Sketch of a portion of an *Anacharis canadensis* leaf after exposure to 100 ppm 2,4-D. The area inside each block of blackened cells is dead (yellowish) and the rest of the leaf is green.

In an attempt to produce the black rings in *A. densa* some leaves from the growing tip were placed in a strong concentration of 2,4-D. In four days the leaves had bleached to a light yellow and no black rings had appeared. The midrib still was faintly green at this time. Cyclosis was present only in the midrib cells where it was very active.

Apparently the midrib cells are the last to be affected.

Anacharis leaves demonstrate cyclosis very favorably and some striking differences were observed in the rate of cyclosis in various parts of the same leaf. The rate was much greater in cells adjacent to injured areas than in cells farther away. This was the case in every injured area examined. The number of stimulated cells surrounding the dead tissue was greater along the longitudinal axis of the leaf than in a transverse direction. Cyclosis in the midrib cells was also increased. A single injured leaf with an active cyclosis was kept on a slide under the microscope for two and one-half hours. During this time water was added to the slide a number of times and the cyclosis rate remained unchanged. A drop of saturated 2,4-D solution was then added to the preparation. The cyclosis rate slowed immediately and completely stopped in 3 minutes. No plasmolysis was evident in any of the cells of the leaf, so it is probable that the stoppage was directly due to the action of the chemical. The experiment was repeated with the same result. A concentration of 100 ppm 2,4-D apparently stimulates cyclosis in the region surrounding blackened areas but a stronger concentration inhibits cyclosis in the whole leaf.

On the ninth day of the experiment a few *A. canadensis* plants which had been treated with 100 ppm 2,4-D were replanted in an untreated aquarium along with some control stock. Some of the plants were entirely yellow (rare, as noted above) and the others had blackened leaf areas and nodes. A month later this series of treated plants had fragmented while the control was growing well. The fragments of the blackened plants were still green. In a similar experiment plants which had been in 10 ppm did not recover their former vigor but remained in the same condition as when they were removed from the treated water. Plants treated with 1 ppm and placed in an untreated aquarium survived and appeared healthy a month later. *Anacharis* plants injured by 2,4-D are unable to maintain themselves even if removed from the treated water.

After the experiment at 100 ppm was terminated, other untreated *Anacharis* plants were placed in the same aquarium to see if they would survive. These plants fragmented and dispersed in the aquarium in a week, demonstrating that a toxic effect of 2,4-D was still present. The plants had broken at the nodes and the fragmented ends were black. The ends of the plants which had been placed in the sand were blackened. Adventitious root tips also showed erosion. These *Anacharis* were removed and replaced with other healthy plants. Again fragmentation occurred. The 2,4-D is therefore still present in toxic concentrations either in the water or in the soil two and a half months after it was added to the water. It is possible that destruction of the 2, 4-D is so slow in water that it might have a permanent or semi-permanent toxic effect on natural waters treated in this manner.

EXPERIMENTS WITH VALLISNERIA

Vallisneria spiralis plants were subjected to the same 2,4-D concentrations as *Anacharis*. Again 1 ppm 2,4-D harmed the plants very little, if at all. The action of the chemical on *Vallisneria* in concentrations of 10 and 100

ppm was slower than on *Anacharis* but was just as effective. After nine days' treatment in 100 ppm 2,4-D a few of the *Vallisneria* leaves turned brown at the base while the upper portions remained green. The leaves became progressively browner and by the thirteenth day a few were curling at the base. Curling was very pronounced on the seventeenth day and increased as time went on. By the twenty-third day many of the individual leaves were dead. Of 12 plants one had died and another was very nearly killed. Practically all the plants were destroyed after being exposed to 100 ppm 2,4-D for thirty days. At this time a rootstock taken from the soil was a black, decaying mass.

Vallisneria was definitely inhibited by 10 ppm. Curling took place in this concentration but the leaves were still green two months after treatment was begun. The most pronounced general effect was that the plants were definitely shorter due to the curling, and the leaves were much narrower than those of untreated plants growing a similar length of time.

Plants in untreated water all remained healthy throughout the two-month period of experimentation.

OTHER PLANTS

A *Myriophyllum* plant was placed in a two-gallon aquarium with 100 ppm concentration of 2,4-D. In three days the leaves had completely shattered leaving the stem bare. The control plant growing in untreated water was healthy.

A heavy growth of the alga, *Cladophora*, was placed in 100 ppm 2,4-D and in untreated water. No difference between the treated and untreated alga was noted after the experiment had progressed a month. More gas bubbles formed in the treated alga, causing it to float on the surface. This might indicate an increased photosynthetic rate.

DISCUSSION

The results clearly show that 2,4-D can be used to destroy four species of submerged aquatic plants. It is highly probable that other species would be equally affected since the chemical acts on such a wide variety of plant forms. Apparently the filamentous alga, *Cladophora*, is unaffected. This is unfortunate since algal blooms are common, and control measures are highly desirable in some cases. All vascular plants tested were strikingly affected by a concentration of 100 ppm 2,4-D and showed a pronounced inhibition in 10 ppm. Probably 25 ppm would be adequate to control most aquatic vegetation.

Toxicity of 2,4-D to fishes and other aquatic organisms is an important consideration. King and Penfound (1946) report that there was a slight mortality among fingerling largemouth bass and bluegills exposed to 100 ppm 2,4-D. During the experiments considered here there was a large population of rotifers (*Philodina*) living in some filamentous algae which developed in an aquarium containing 100 ppm 2,4-D. Pond snails lived in all aquaria throughout the experiments, which in some cases lasted two months. One snail died in 100 ppm but others were living in the same aquarium so the death could not be directly attributed to the effects of 2, 4-D. 2,4-D seems to affect aquatic animal organisms very little in concentra-

tions up to 100 ppm, as based on these observations.

King and Penfound (1946) also mention that a high mortality of small largemouth bass and bluegills resulted when treated water hyacinth (an emergent plant) began to decay, creating a high biological oxygen demand (B.O.D.) As judged by the experiments reported here, the destruction of submerged aquatics is much less rapid than than that of emergent forms. It is possible that the B.O.D. might be kept at a reasonably low level in treating submerged aquatics and that the death of fishes due to lack of oxygen could be avoided. Experiments on ponds are needed to verify this assumption.

Before the work of this paper was complete, Surber, Minarik and Ennis (1947) reported that *Anacharis canadensis, Naias flexilis, Potamogeton nodosus, Potamogeton crispis, Potamogeton foliosus,* and *Potamogeton filiformis* are affected by 2,4-D and other phenoxyacetic compounds. They showed that *A. canadensis* can be killed by 5 and 10 ppm 2,4-D in aquaria but was not effective when added to ponds at a rate of 10 pounds per acre. The writer would place the concentration of 2,4-D necessary to kill *Anacharis* at a somewhat higher level than 5–10 ppm. Based on the experiments reported here it seems that at least 25 ppm would be required to insure eradicating the plants. Perhaps the discrepancy lies in differences in the chemical constituents of aquarium water, light and temperature, season of the year at which the experiments were conducted, different physiological state of the plants, etc.

Economic considerations are always paramount in considering the worth of control measures. The 2,4-D concentration required for control of submerged aquatics lies between 10 and 100 ppm, probably in the order of 25 ppm. Based on present market prices ($1.55 to $1.65 per pound), it would cost approximately $67 to treat one acre foot of water with 25 ppm 2,4-D. Ponds of 0.5 acre have about 2.5 acre feet of water and it would cost $167 to treat such a pond. Since the cost of a pond of this size is sometimes as low as $350, it would hardly seem justifiable to spend half that amount controlling submerged aquatic plants.

SUMMARY

1. Need for the control of submerged aquatic plants is so great in some cases that laboratory experiments on dense growths of four species were carried out using 2,4-dichlorophenoxyacetic acid (2,4-D) as the herbicide. The 2,4-D was dissolved in aquarium water in which the plants were growing.

2. *Anacharis canadensis, Anacharis densa, Vallisneria spiralis* and *Myriophyllum* sp. were all killed in a 2,4-D concentration of 100 ppm and are definitely inhibited in 10 ppm. A concentration of 25 ppm is likely to be effective on most submerged aquatic plants.

3. The alga, *Cladophora,* was unaffected by 100 ppm 2,4-D.

4. Although 2,4-D can be used to control submerged aquatic plants, the present cost of the chemical is so great that its general use will probably be limited.

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YIELD AND USE BY WILDLIFE OF ACORNS OF WATER AND WILLOW OAKS[1]

Eugene Cypert and Burton S. Webster

Branch of Wildlife Refuges, Fish and Wildlife Service

This paper presents the results of a study of acorn production and utilization in water oak (*Quercus nigra*) and willow oak (*Quercus phellos*) conducted from 1938 through 1940 on the White River National Wildlife Refuge in Arkansas. The importance of the acorns of these species as duck food prompted the study. Information on the amounts of mast produced in relation to age and size of the trees and its utilization by wildlife other than ducks was needed, since such information would be useful in establishing timber harvesting policies.

It is realized that, because of the cyclical production and individual variation in acorn production, this study is too limited, both as to the number of seasons covered and the number of trees studied, to serve as a basis for generalizations about total mast production. It is of value, however, in showing the use of acorns by wildlife and in pointing the way to further studies on mast production. Additional information is needed to determine more accurately the age and size at which the maximum amount of mast is produced by these trees. Data of this sort would provide a sound basis for timber management. Downs and McQuilkin (1944) have made such studies of some of the oaks of the Appalachians, but because of the differences in sites and species, it is believed that the ages and sizes at the time of greatest production of those oaks will differ from the oaks of the lower Mississippi and Gulf Coast plain.

The White River National Wildlife Refuge is located in the Mississippi delta region of the lower White River in Arkansas. Here water and willow oaks are to be found on low ridges, washboardy sites, and flats of first bottoms which usually are flooded continuously in late winter and early spring and on poorly drained flats of second bottoms subject to occasional flooding during late winter and spring (Putnam and Bull, 1932). These species are commonly associated with red gum (*Liquidamber styraciflua*), cherry bark oak (*Quercus rubra pagodaefolia*), Nuttall oak (*Q. nuttallii*), cow-oak (*Q. prinus*), Ameri-

[1] The writers are indebted to Mr. Robert H. Smith who outlined the methods for this study, and to Mr. Howard A. Miller for suggestions and criticisms during the progress of the work.

can elm (*Ulmus americana*), and cedar elm (*U. crassifolia*).

METHODS

The trees in this study were located on a first bottom ridge in a red gum-Nuttall oak-willow oak association (F86 of the Society of American Forester's Standard timber types). Fifteen trees in similar sites of each of the species in question were selected. All were dominant or co-dominant and thrifty. Records of the d.b.h., age, height, crown height and crown diameter were taken of each. See information given in Table 1.

One-tenth of the canopy area was staked off with 1″×4″ boards to form triangular plots extending along the ground from the bole of the tree to the periphery of the canopy area. These plots were cleaned of debris at the beginning of each season and swept each time the acorns were collected.

Acorns were collected once each week and counts made of whole acorns with caps, whole acorns without caps, partly eaten acorns with caps, partly eaten acorns without caps, empty acorns with caps, empty acorns without caps, empty caps, and abortive acorns.

TABLE 1.—TREE MEASUREMENTS AND ESTIMATED PRODUCTIONS OF ACORNS

Tree no.	Species	DBH	Crown height	Age	Crown diameter	Estimated total number of acorns produced		
						1938	1939	1940
1	*Quercus nigra*	31″	98.0′	124 yrs.	46.0′	8,720	93,000	28,360
2		24″	71.0′	65 yrs.	47.0′	4,800	11,720	22,000
3		22″	59.0′	64 yrs.	39.0′	2,182	4,237	2,025
4		20″	61.0′	42 yrs.	38.5′	1,444	3,700	2,051
5		12″	45.0′	60 yrs.	33.5′	906	5,102	1,985
6		24″	69.0′	25 yrs.	42.5′	6,420	7,500	23,150
7		16″	49.0′	43 yrs.	35.5′	790	869	1,804
8		19″	65.0′	34 yrs.	33.5′	3,130	13,190	2,168
9		23″	53.0′	68 yrs.	46.5′	3,550	5,950	15,320
10		18″	44.0′	59 yrs.	42.5′	274	2,132	7,670
11		26″	79.5′	93 yrs.	54.5′	6,890	7,080	11,920
12		15″	61.5′	75 yrs.	34.5′	2,171	3,182	8,500
13		20″	80.0′	80 yrs.	27.0′	7,720	9,276	7,760
14		22″	62.5′	85 yrs.	38.0′	1,434	4,345	775
15		13″	44.5′	50 yrs.	29.5′	327	1,230	96
16	*Quercus phellos*	23″	57.0′	70 yrs.	47.0′	1,568	2,450	3,720
17		30″	67.0′	67 yrs.	41.0′	2,344	3,885	3,179
18		19″	55.0′	43 yrs.	38.5′	5,075	52,220	8,750
19		14″	43.5′	25 yrs.	40.5′	95	622	0
20		30″	62.0′	61 yrs.	61 0′	1,120	12,200	4,425
21		31″	75.0′	91 yrs.	60.0′	2,680	15,100	6,425
22		26″	62.5′	87 yrs.	51.5′	8,100	9,300	6,125
23		17″	50.0′	42 yrs.	34.5′	3,480	5,310	5,435
24		20″	56.5′	36 yrs.	34.5′	3,720	10,140	9,980
25		19″	51.0′	33 yrs.	36.5′	3,380	9,350	5,275
26*		35″	100.0′	111 yrs.	76.5′	9,450	7,380	10,350
27		18″	36.0′	45 yrs.	37.5′	4,950	11,890	2,145
28		22″	50.0′	56 yrs.	41.5′	1,604	14,790	8,680
29		13″	38.5′	37 yrs.	34.0′	1,765	9,150	5,865
30		14″	44.0′	37 yrs.	29.0′	342	1,200	0
Total						101,439	337,510	215,938

* A different tree in 1938 from that of the other two seasons because of wind damage to original tree.

In order to discover the acorn removal from the ground by birds and rodents in the daytime and by rodents at night, twenty marked acorns were placed on each plot at periods throughout the mast season. They were counted at about sunrise and sunset each day. Missing acorns were replaced at the time of counting.

In order to learn the number of acorns removed from trees during daylight hours by birds and rodents, observers were stationed at points where removals could be seen and a record kept of the acorns carried away from the trees and the length of time of observations. Counts were also made of acorns that fell on the plots during the time the observations were being made. In 1939 seasonal records were kept of removals from seven trees, numbers 1, 2, 6, 7, 8, 13, and 23. This method was changed in 1940 with observations first on one tree, then on another, so that records were obtained on twenty-two during the season.

VARIATIONS IN YIELD

It is interesting to note that there is considerable variation in the dates that individual trees drop their acorns. Table 2 lists the peak period of acorn fall for each tree. In 1939 the peak was reached by tree No. 1 during the first week in September and by tree No. 8 the last week of November.

There is also considerable seasonal variation in the period of dropping. In 1938 most of the trees reached this peak the last week in September, while in 1939 it was delayed until the third week in November.

It is not meant to imply that a tree will drop most of its acorns within the period of a week during any one season. On the contrary, it was noted that most of the trees began dropping their acorns in early September and continued into December. But, it does appear that there is a variance in the period during which most of the acorns ripen on individual trees without regard to age or site.

Not only was there a difference in the time of the dropping of acorns in individual trees, but there was also a great variation in the quantity of acorns produced by individual trees of the comparative age and size growing under apparently similar conditions, as can be seen in Table 1.

ACORN REMOVALS

Acorn removals from the ground, as described above, were recorded September 27, 28, and 29 and October 7 and 8 in 1938 and once each week from September 17 through the month of November in 1939. Removal in 1938 was 5.0 per cent during the day and 0.6 per cent during the night. Removal in 1939 was 3.5 per cent during the day and 1.6 per cent during the night.

Complete data are lacking on the species of animals and the quantities removed, but it is known that grackles (*Quiscalus quiscula aeneus*) account for some of the removal during the day and that flickers (*Colaptes auratus*) occasionally pick up acorns from the ground. Probably mice (*Peromyscus sp.*) and flying squirrels (*Glaucomys volans*) are responsible for most of the night losses. While the site on which this study was made is typical of those on which ducks feed in White River bottoms, ducks were not observed in this immediate vicinity during the study, and it is not

TABLE 2.—PERIODS AT WHICH EACH TREE YIELDED MOST ACORNS DURING THREE YEARS

Tree no.	Period of Greatest Yield		
	1938	1939	1940
1	Sept. 15–Sept. 21	Sept. 1–Sept. 8	Sept. 8–Sept. 15
2	Sept. 21–Sept. 26	Nov. 17–Nov. 23	Nov. 14–Nov. 20
3	Oct. 7–Oct. 13	Nov. 17–Nov. 23	Oct. 16–Oct. 24
4	Sept. 15–Sept. 21	Nov. 17–Nov. 23	Oct. 3–Oct. 9
5	Sept. 21–Sept. 26	Sept. 23–Sept. 29	Oct. 3–Oct. 9
6	Oct. 1–Oct. 7	Nov. 17–Nov. 23	Nov. 14–Nov. 20
7	Oct. 30–Nov. 8	Nov. 17–Nov. 23	Sept. 18–Sept. 25
8	Sept. 21–Sept. 26	Nov. 23–Nov. 30	Oct. 3–Oct. 9
9	Sept. 21–Sept. 26	Nov. 17–Nov. 23	Oct. 14–Oct. 20
10	Sept. 21–Sept. 26	Nov. 17–Nov. 23	Sept. 18–Sept. 25
11	Oct. 19–Oct. 25	Nov. 17–Nov. 23	Oct. 14–Oct. 20
12	Sept. 21–Sept. 26	Nov. 17–Nov. 23	Oct. 16–Oct. 25
13	Sept. 15–Sept. 21	Nov. 17–Nov. 23	Oct. 9–Oct. 16
14	Oct. 13–Oct. 19	Nov. 17–Nov. 23	Oct. 26–Nov. 2
15	Oct. 25–Oct. 31	Nov. 17–Nov. 23	Oct. 26–Nov. 2
16	Sept. 21–Sept. 26	Nov. 17–Nov. 23	Sept. 18–Sept. 25
17	Sept. 21–Sept. 26	Sept. 30–Oct. 6	Sept. 18–Sept. 25
18	Sept. 21–Sept. 26	Nov. 23–Nov. 30	Sept. 18–Sept. 25
19	Oct. 1–Oct. 7	Nov. 9–Nov. 16	None produced
20	Sept. 26–Oct. 1	Sept. 23–Sept. 29	Sept. 18–Sept. 25
21	Sept. 21–Sept. 26	Nov. 17–Nov. 23	Sept. 26–Oct. 2
22	Oct. 7–Oct. 13	Oct. 20–Oct. 26	Oct. 17–Oct. 25
23	Oct. 19–Oct. 25	Oct. 6–Oct. 12	Nov. 8–Nov. 15
24	Oct. 19–Oct. 25	Nov. 17–Nov. 23	Oct. 3–Oct. 9
25	Oct. 19–Oct. 25	Nov. 17–Nov. 23	Nov. 8–Nov. 15
26*	Oct. 7–Oct. 13	Nov. 2–Nov. 9	Oct. 10–Oct. 16
27	Sept. 26–Oct. 1	Oct. 6–Oct. 12	Oct. 10–Oct. 16
28	Oct. 1–Oct. 7	Nov. 17–Nov. 23	Oct. 10–Oct. 16
29	Oct. 31–Nov. 8	Oct. 13–Oct. 19	Oct. 17–Oct. 24
30	Oct. 19–Oct. 25	Sept. 9–Sept. 15	None produced

* A different tree in 1938 from the other two seasons.

believed that they accounted for any removals.

The number of acorns taken from the trees by blue jays (*Cyanocitta cristata*) and red-headed woodpeckers (*Melanerpes erythrocephalus*) was surprising. Seven trees were watched at intervals for acorn removals September 12 to November 22 in 1939, and observations were made in twenty-two trees from October 4 to December 2 in 1940 to learn the removal by birds and squirrels. Only acorns actually removed from the trees were counted. Nearly all taken by woodpeckers were carried away, probably to be eaten or cached elsewhere. Part of the acorns taken by blue jays were eaten on the spot, which accounted for many of the partly eaten or empty acorns. An estimate of the number of acorns removed was arrived at by multiplying the average hourly removal by the daylight hours for each week during the season. It will be seen in Table 3 that an estimated 13.8 per cent of the entire acorn crop was removed in 1939 and 12.8 per cent in 1940. This includes only acorns actually removed from the trees and not those eaten on the spot or removed from the ground.

TABLE 3.—PERCENTAGE OF ACORNS REMOVED FROM THE TREES, EATEN IN THE TREES, OR DAMAGED BY BIRDS

Year	Blue jays	Red-headed woodpeckers	Others	Empty acorns	Acorns partly eaten
1938				*14.4*	*11.9*
1939	*6.2*	*5.6*	*2.0*	*8.6*	*18.4*
1940	*5.1*	*5.7*	*2.0*	*4.8*	*36.5*

In 1939 simultaneous counts were made of the number of acorns removed from the trees by the birds and those falling to the ground. These counts showed the removal by birds to be 12.7 per cent of the total acorn yield.

In addition to the blue jays and the red-headed woodpeckers, other species accounting for an acorn loss of 2.0 per cent were grackles, flickers, and red-bellied woodpeckers (*Centruus carolinus*), Carolina wrens (*Thyrothorus ludovicianus*) and, rarely, fox squirrels (*Sciurus niger rufiventer*). Table 3 shows the percentage of these removals and of the empty and partly eaten acorns collected.

The percentage of empty acorns collected was 14.4 in 1938, 8.6 in 1939, and 4.8 in 1940. These figures added to the acorns which were carried from the trees show that 22.4 per cent in 1939 and 17.6 per cent in 1940 never reached the ground. Since the removal of the acorns on the ground amounted to something more than 5 per cent each 24 hours, it can be anticipated that few acorns will be found but a few days after the last of the crop falls.

SUMMARY

A study was made of the acorn production of water and willow oaks from fifteen trees of each species. Acorns were collected from plots sampling one-tenth of each crown. Marked acorns were placed on the plots to ascertain the percentage of removal from the ground by birds and rodents. From time to time observers were stationed nearby to count the number of acorns removed from the trees by wildlife.

The period at which most acorns were dropped differed with individual trees. The peak was reached in one tree as early as the first week in September and in another tree of the same species as late as the last week in November of the same year.

The period of greatest acorn fall also varied with the season. It was found that trees may drop most of their acorns as early as the last week in September one year and in another as late as the third week in November.

There also appeared to be a great difference in acorn yield between trees of the comparable size and age and similar site.

The removal of marked acorns from the ground by birds and rodents amounted to slightly more than 5 per cent during each day and night.

The removal from trees by birds amounted to from 12.8 per cent to 13.8 per cent and those eaten in trees amounted to from 4.8 per cent to 14.4 per cent.

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UNIFORMITY OF EXPRESSION IN GAME MANAGEMENT

Ralph R. Hill
Denver, Colorado

and

James W. Kimball
Pierre, South Dakota

Standardization has been the key to progress in many fields. Music remained primitive until a uniform method of expression was adopted. Production in the field of mechanics was limited until the standard thread, the S.A.E. thread, and other standards were accepted. The more advanced sciences such as mathematics, physics, and chemistry are dependent upon standards of expression. In the opinion of the authors, wildlife management is now suffering for a lack of standardization of terms of expression.

Density, with reference to game, has been defined by Leopold (1936) as the number of individuals per unit area. Wight (1931) stated that satisfactory methods in upland game bird investigations must be both quantitative and standardized, and the results expressed in birds per acre. Other authors, without specific suggestions, have expressed the need for standards.

A review of articles published in The Journal of Wildlife Management and papers presented at North American Wildlife Conferences for the past five years disclosed 54 articles in which animal population densities, carrying capacities, or yields were expressed proportionately. In 25 instances ratios were given in terms of acres-per-animal. Animals-per-acre was used 12 times; animals-per-10-acres, once; animals-per-100-acres, 7 times; animals-per-section (or square mile), 12 times; and animals-per-township, once.

No clearly defined acceptance of regional standards was discernible, nor was there uniformity in treatment of species. Of the species covered in two or more discussions, muskrats alone received similar treatment—animals-per-acre—but yields of their pelts were in terms of both acres-per-pelt and pelts-per-section. Authors were reluctant to divide a single animal into decimal parts per acre, but less so to carry a fractional animal with one or more whole ones.

Frequency of occurrence, abundance of one animal in relation to another, and the use of such terms as "common" and "rare" have been suggested; but, for general use, they lack specificity. The advantages of uniform terminology would appear to be obvious; and, with some degree of flexibility, uniformity should be attainable. (It is appreciated that important details are obscured in averages, and that improper use of percentages can result in serious errors; nevertheless, reductions to units of area have an important place if properly used). The arithmetic involved in converting terms to one's own form of expression is aggravating, but this is incidental to other arguments for common usage.

Without standardization, important

factors of competition, tolerance between species, predatory relations and buffer species may be obscured. Graham (1929) expresses this thought as follows: "Another advantage of the general use of certain standardized methods lies in the fact that biotic phenomena of one kind may have an important influence on phenomena of quite a different nature. Sometimes these effects are local, but in other instances they may have an influence even in distant localities. If our information concerning various kinds of biotic phenomena were expressed in standardized terms, greater correlation of data would be possible, with the result that relationships heretofore unsuspected might be brought to light." The coming emphasis on yield tables should be reason enough to settle upon common terms of expression.

The use of acres as a measure of surface area seems to be acceptable in the United States and Canada, but expressions of acres-per-animal and animals-per-acre (or 100 acres, or 640 acres) are about equally divided.

Acres-per-animal has one advantage: It is never necessary to mathematically dissect an animal to fit the equation; the acre, being somewhat intangible, is cut with less reluctance. The disadvantages are several. It is not a clear way to express yield tables, nor to compare two or more species on a given unit of range. A separation of sexes or age classes within a species is neither readily accomplished nor comparable. High figures indicate low production, the equation being inverse for anything but area requirements. If it were an indication of the animal's territorial requirement, or cruising radius, or saturation point, there would be more reason to retain it; but this is seldom the case because the family, flock, or herd unit extends the territorial requirement somewhat in proportion to the numbers involved. Its application to a larger land area in most instances requires the process of division which is less simple than multiplication. Furthermore, it emphasizes the crop rather than the basic land resource, and tends to obscure the ecological reactions—both plant and animal—within the environment.

Few people have worked extensively enough with land to be able to visualize odd acreages. The expression, "100 animals per section (square mile)," is easily visualized while, "one animal per 6.4 acres," is obscure because few of us have a mental picture of a 6.4 acre tract of land.

Generally, the disadvantages of the acres-per-animal system are the advantages of the animals-per-acre (or multiples of an acre) system. The advantage of the first system in precluding a fractional single animal can be compensated in the second system as described later.

Animals-per-section (or square mile) is a commonly used expression, particularly with reference to deer. Areas in square miles are easily obtainable from most maps, and fit in well with the public land survey systems of the United States and Canada. In comparatively level areas of much of the middle west, road systems divide the land into mile-square blocks and the land use patterns about them. Throughout livestock ranges of the West the section is a common unit of measure. The disadvantage of a section unit is that it is not readily divisible for comparison with the smaller units used for upland birds,

small game, and non-game animals such as the smaller rodents. It may not be acceptable in those states where metes-and-bounds surveys rather than the rectangular survey system prevail.

The use of birds-per-100-acres seems to have been accepted by many technicians and game managers. This, together with other decimal modifications of the animals-per-acre system, has the advantage of dealing with at least one animal per unit of land area. The results can be converted readily for comparisons or for application to larger or smaller areas by shifting decimal points. The principle can be applied as well to animals-per-thousand-acres where conditions justify.

The following tabulation illustrates the use of five different but equivalent forms of expressing density. The advantages of an animals-per-acre system, particularly the decimal modification. where two or more species are involved, should be evident.

Form of expression	Density by species		
	Total deer density	Mule deer (40%)	White-tailed deer (60%)
Acres per deer	25	62.5	41.25
Deer per acre	0.04	0.016	0.024
Deer per 100 acres	4	1.6	2.4
Deer per section	25.6	10.24	15.36
Deer per 1000 acres	40	16	24

Suppose the preceding tabulation is representative of a foot-hill winter deer range where ponderosa pine is taking over a temporary oak brush type. Succession toward a pine climax is reducing the deer carrying capacity. The game manager may determine that by reducing the stocking of pine to 50 per cent he can encourage oak and other hardwood browse so that the area will support 100 deer instead of only 40 deer per M acres. But, by reducing the stocking of pine, he may lower the annual rate of sawtimber increment from 80 bd. ft. to 40 bd. ft. per acre—a per thousand acre reduction of 40 M ft. b.m. At $5.00 per M ft. b.m. the loss of timber revenue is $200 annually (less the value, if any, of the current cutting). This loss is offset by an additional winter capacity of 60 deer which should yield 12 to 15 harvestable deer annually. The land-owner can then decide whether the increase in the deer crop is worth as much as or more than the loss in timber crop. The proposition is stated in terms that he can understand.

But, suppose the game manager, using the identical situation, calculates in terms of acres-per-deer. He proposes to raise the density from 25 acres per deer to 10 acres per deer, an increase of one deer to $16\frac{2}{3}$ acres. This is calculated to increase the yield from one deer to $83\frac{1}{3}$ acres, to one deer to $66\frac{2}{3}$ acres annually, and is obtained with a corresponding loss of a thousand board feet of timber to 25 acres. Stated in this way, a meeting of minds would be unlikely. So, for expressing density, carrying capacity, or yield, the authors favor an expression in terms of animals-per-acre or a decimal modification thereof.

In the midwest and west it may always be necessary to express populations of both large and small game as animals-per-section when working with the public. However, if 100 acres is established as the working unit, this, as well as the section, can be included in scientific writings.

A need for standardization also arises

where land area is not a factor. When recording large or small game on a roadside count or transect the question arises as to whether to express the results in animals per mile, or miles per animal. A question also arises in censusing game by ear. Should pheasant, grouse, quail or other species be recorded as calls per unit of time or unit of time between calls? In both of these instances we again recommend that the unit of distance and the unit of time remain constant and the animal, whether seen or heard, be the variable.

Standardization in stating ratios is also needed. The Wildlife Society has standardized the expression of sex ratios as males per 100 females. This is very satisfactory. There is also need for a standard method of expressing age ratios. These are now being expressed as per cent young, adults per young, young per adult, females per young, and young per female. We believe that age ratios, like sex ratio, should be expressed using either 1 or 100 females as a unit. Thus, three young for each adult female would be expressed as 3:1 or 300:100. To condense tables it could be expressed as simply 3 or 300. To express the number of young in relation to the total adult population, 1 or 100 adults could be used as a unit. While thinking in terms of reproduction it seems more logical to express the ratio as 2 young per adult than to state that 67 per cent of the population is young. Expressing age ratios in per cent is also highly misleading. If reproduction increases from 2 young per adult to 3 young per adult, the percentage method shows an increase from 67 to 75 per cent. This implies an increase of only 8 per cent (which is correct for the composition of the population) but reproduction has actually increased 50 per cent.

Standardization is also recommended in the method of expressing combined sex-age ratios by using a decimal system on the females. Here again we recommend the use of 100 females as the unit. For example, buck:doe:fawn ratios are commonly expressed by using one buck as a base as follows: 1:4:4.8. Expressing this ratio as 25:100:120 seems preferable. By so doing all figures are given in per cent of females as well as being a ratio which can be used without further calculation.

Other needs for standardization appear in expressing kill date. Shall it be birds per hour or hours per bird, deer per hunter or percentage of hunters successful? Most game men use the time element as the variable while the animal remains the constant. However, we notice that, with fish at least, some workers are expressing success in fish per hour. It may be determined that time should be the constant even in expressing hunter success.

In considering standardizations of the nature discussed in this paper we may do well to refer to usages which have been standard for a long period of time in such sciences as mathematics, chemistry, physics, engineering, etc. Among the standardizations which seem to relate directly to this paper are these general forms: $X = Y/A$ and $X = Y/T$ where X and Y are variables and A and T represent area and time respectively. It will be noted that in these two cases area and time are used as constants.

In conclusion, the function of this paper in recommending certain standards is secondary. Its primary purpose

is to emphasize the need for the establishment of standards of expression which will be taught in the wildlife schools and used uniformly in the field.

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METHODS OF CONTROLLED PUBLIC HUNTING IN THE UNITED STATES AND CANADA

Walter E. Scott

Wisconsin Conservation Department, Madison, Wisconsin

When the Wisconsin Conservation Department embarked upon its first controlled hunt on antlerless deer in the Necedah National Wildlife Refuge in 1946, a survey was made of all states and Canadian provinces to determine their experiences with such projects. Replies indicated that control by limitation of the number of hunters was the most prevalent method used. This report is a result of that study.

Controlled hunting is defined here as the orderly harvesting of wildlife through an equitable and pre-determined distribution of hunter pressure on lands open to the public. It implies the imposition of additional restrictions upon the hunter, but it is not simply a matter of regulating his harvest or checking his success; it requires also the pre-season selection of a limited number of hunters who will participate in the harvest. Upon the degree of fairness with which this selection is made may well rest the success of any controlled hunting program.

Historically, wildlife in America is held in trust for all the people by the state. As early as 1629 persons settling in the New Netherlands were given charter privileges to hunt and fish by the Dutch West India Company. The Constitution of Pennsylvania in 1776 formally declared for the public the "liberty to fowl and hunt." However, as early as 1710, some methods used in hunting were condemned in Massachusetts, and restrictions on the use of blood hounds in hunting appeared in 1788, while prohibitions on night hunting and the use of big guns were imposed in 1832. From those dates onward more and more regulations were placed upon the so-called "freedom of hunting,"climaxed by the first hunting license law in the United States established by New York in 1864. This introduced a period of ever-increasing regulation.

The development of more hunting restrictions over the years is a common story for each state, but these rules dealt largely with bag limits and length of season. By 1920, Edward A. Goldman of the Biological Survey spoke of the threatened extinction of many forms of wildlife due to the changing conditions brought about by man. Besides the rapid settlement of the country, he mentioned modern automatic firearms,

the automobile, better roads and faster travel, culminating in the airplane. He stated that more than three and one-half million hunting licenses were sold in 1919. Twenty-five years later, in 1944, license sales had increased over 100 per cent and all the problem conditions he mentioned were well developed. Wildlife had suffered serious inroads on its numbers, but stricter enforcement of both old and new regulations and new management techniques had saved the day for many species of wildlife.

The stage was set for the biggest problem of all: where were these millions of sportsmen to hunt and how was over-harvesting due to their concentrations to be prevented? Wider accessibility from urban areas had resulted in a wave of posting of private lands against trespass, while the newly available resources of the pheasant and built-up herds of big game were an attraction to hunters. In general, the problem of the heavily populated eastern states was one of managing the harvest of small game, and especially pheasants, on private farm land, while that of the western states was one of managing big game herds on public range and forest lands. In either case, the number of hunters had to be regulated to prevent too great a harvest in certain areas or on certain species. Attempts to solve the farm trespass problem also were a primary element in controls established in eastern states.

Controlled hunting of big game supervised under state authority dates back to 1927, when Utah issued 150 permits to harvest elk from a herd that needed reduction. On small game, one of the first controlled projects was that set up in Michigan's Williamston Township by the Izaak Walton League, and operated as a cooperative venture with the state Conservation Department and University after 1930. This project centered largely around the pheasant, but all small game was involved. In rapid succession, most all other western states embarked upon controlled hunts for various big game herds in need of special management practices, and the so-called Williamston Plan was used with variations throughout most of the populated pheasant states.

At the present time it can be said that at least 30 states have had experience with some form of controlled hunting. Twenty-two have had controlled hunts on big game and nine on small game. Antelope, buffalo, elk, moose, bear, wild boar, and several species of deer figured in such big game hunts, while those for small game generally are based upon pheasant or waterfowl with other animals considered incidental to the plan. Because there is usually a great difference between the big or small game-controlled hunts, they will be considered here separately.

The importance of controlled hunting on big game was stated clearly by H. L. Shantz of the U. S. Forest Service in 1938, when he reported that, "Regulated hunting is recognized as the only remedy for the over-concentration of big game on many of the National Forests. Continual buck hunting does not control over-populations. . . . " These harvests at first were mainly on small herds which would have suffered from considerable over-shooting by uncontrolled harvesting. A case in point is Wyoming's first season on antelope in 1929. Over-concentrations of hunters

practically exterminated the animal in four counties. Since 1933, controlled hunts have solved this problem and met with public favor. At the present time, more western states are using this system on their larger herds of deer to reduce over-populations on certain ranges.

The general procedure on these hunts is to ascertain from surveys the needed herd reduction, determine from past experience the number of permit hunters needed to make the necessary harvest, and publicize the regulations of the hunt. In 17 states, hunters for such controlled harvests on big game were selected by public drawing or lot, but it is a surprising fact that frequently sufficient applications were not received and no drawing was necessary. This may have been due to the inaccessibility of the areas to be hunted. Seven states have held big game hunts in which those who applied first or arrived first on location were given permits. This system does not seem to be so good for administrative reasons, but may meet local conditions better.

It has been found that sportsmen favor controlled hunts for big game either because it increases the recreational value of hunting by preventing overconcentrations of hunters, or it makes possible harvests on small herds. Ranchers have favored the harvests because it is a method whereby damage to the range by small herds often can be controlled without eliminating the herd altogether. In both Wyoming and Texas, ranchers have gained some financial returns through hunters' fees or credit for animals shot on their property. Herds regulated in this manner frequently have been improved to the extent that they have more trophy possibilities for sportsmen in future years. It seems to be preferable to charge a reasonable fee for permits issued in controlled big game hunts. This practice helps to defray administrative expenses and discourages applications from those who may not plan to use their permit.

In nine southeastern states, a total of 25 Cooperative Wildlife Management Areas, with a minimum size of 50,000 acres, have been set up on National Forest lands in cooperation with the states. On 11 of these units, controlled fishing and hunting is practiced even to the extent of wild boar and bear hunting on a party basis and special "wilderness hunts" into inaccessible areas. Whenever necessary, selection of hunters is accomplished by a drawing.

Pennsylvania, Michigan, Minnesota, Ohio and Wisconsin are the only north central and northeastern states with experience in controlled big game hunts. These are usually for antlerless deer, and still on a small scale except for Pennsylvania's 1946 antlerless deer season by special permit in several counties. The legal authority for such limitation of hunters is lacking in many of the states in this area. However, Wisconsin's controlled hunt on antlerless deer was operated through trespass powers of the Fish and Wildlife Service on lands supervised by them. In Wisconsin's hunt in 1947 almost 20,000 sportsmen applied in hunting parties for the available 6,000 permits. Although administration was complicated by so many applicants, the use of IBM machines to select the permittees and preparation of photostatic copies of their applications to use as permits, facilitated the details considerably.

Controlled hunting on small game species has developed largely in connection with public hunting grounds programs for the primary purpose of securing trespassing rights on farm lands favorable to pheasant hunting. Following the Williamston Plan in essentials, Connecticut had 160,000 acres under permit control in 1946, Pennsylvania three experimental areas in 1937, Michigan a half million acres in 1936, Ohio 15 areas in 1938, New York 122,000 acres in 1943, New Jersey almost 128,000 acres in 1935, and Ontario many units controlled by rural municipalities.

In most of these projects, the farmers were given protection with refuges and regulated car parking, special privileges in controlling issuance of permits and assistance in posting, preparation of ticket-permits, stocking, and improving game conditions. Hunters sometimes paid an additional hunting fee to the farmer, but this generally was frowned upon as poor business. Hunting privileges usually were limited to seasonal permits for the farmers and members of cooperating sportsmen's clubs with limited daily guest permits to outsiders on a first-come, first-served basis. It is obvious that these plans allow for favoritism in selecting hunters, and some are bound to be disappointed on peak days, but the projects did succeed in opening more lands to public hunting. Such units, usually sponsored by conservation departments, still operate in at least six states and provinces.

The experience of New York is important because it was possible to eliminate some defects by leasing their areas at 10¢ an acre, and issuing all permits themselves on an equitable basis, after the farmer's family was given a seasonal permit. No more than three hunters were allowed on 100 acres at a time. They operated full-time checking stations on each area during the pheasant seasons and secured much valuable information. However, in 1943, after the five-year experimental period, this plan was judged to be too costly with an expense figure of $1.56 per permit per man day on even the best area.

The Province of Ontario found that it was necessary to limit the number of special permits issued to hunters for their favored Pelee Island pheasant hunting. In 1939, a total of 1,600 hunters crowded the island with one hunter on each 10 acres. The cooperating farmers were pleased to see these permits limited to only 900 during following years, and the idea spread throughout the province. However, in their plan, rural municipalities setting up such cooperative hunting areas are permitted to charge a fee which goes into the local public treasury.

At present, besides the Williamston Plan cooperatives still active, several states have types of public hunting grounds with only limited hunting permitted. Illinois has six areas of special value for either pheasant or waterfowl for which permits are issued in the order of application. Hunters pick the area and day they wish to hunt. Michigan manages one marsh for waterfowl on which 300 permits are given to those who come first. Any overflow of hunters is shifted to a nearby unrestricted area. Ohio has one area for waterfowl on which a drawing is held to determine the selected hunters. A specified date

and blind number are assigned and alternates are drawn for any who cannot use their permits. In North Carolina the number of available blinds on the Mattamuskeet National Wildlife Refuge's open hunting area is limited, but selection of hunters has not been necessary to date. However, the strict regulations requiring an authorized guide probably reduces the number of applicants. Indiana has had a little experience in limiting waterfowl hunters on one public area to the number of available boats, and Iowa successfully has limited waterfowl hunters on two public areas by determining the number of blind locations and requiring the removal of all blinds at night. Hunters built blinds on their boats and occupied the locations on a first come, first served basis.

SUMMARY

1. In the western states, controlled hunting is now an important management method used especially to prevent over-shooting of both large and small herds of big game and prevent over-concentrations of hunters even where over-shooting might not have serious effect. Most western states have secured legal powers authorizing this type of harvest.

2. In the rest of the country, controlled hunting still is in the experimental stage, except for certain cooperatives on the National Forests in the southeast, and public hunting grounds cooperatives protecting landowner trespass rights, especially during pheasant seasons.

3. Except for the southeastern states, the legal authority to limit hunter numbers in even problem cases frequently is lacking. Although projects such as this can be operated by states in cooperation with federal agencies on their lands, using their trespass powers in issuing permits, enabling legislation would be desirable.

4. Big game herds needing additional harvesting or reduction on inaccessible areas might best be controlled through this method. Over-concentrations of hunters on especially desirable deer, waterfowl, or pheasant areas might be prevented in this way to benefit both the hunter and the game. The selection of applicants and distribution of permits by machine methods can reduce administrative difficulties.

5. Wildlife managers should investigate the possibilities of controlled hunting to solve special problem cases. The value of such projects to research workers through checking stations has been proven in many instances.

6. No one desires to see more restrictions placed upon the sportsmen, but with full understanding of the programs both the sportsmen and the general public often favor such additional regulations which will improve the recreational enjoyment of orderly public hunting and prevent over-harvesting of wildlife resources.

EFFECT OF VOLUME ON THE DETERMINATION OF DDT OR ROTENONE TOXICITY OF FISH

G. Prévost, C. Lanouette, F. Grenier
Biological Bureau, University of Montreal, Quebec

In reference to legislation concerning the effect of pollution on fish, it is the inclination of many, particularly engineers for government institutions and industrial plants, to rely on toxicity data published by experimenters such as Ellis (1937). Although these data may be of some help, they should not be accepted as fully reliable guides. Ellis himself points out: "Arbitrary application of lethality data to specific pollution problems is absolutely impossible, owing to the many limiting factors." We agree with him on this point, but we believe that such data could be made more relevant if in laboratory experiments, in addition to the factor of original concentration, the factor of total poison in the preparation were taken into consideration. Ellis (1937), Belding (1927), and Gersdorff (1930), in their publications on toxicity data specifically in reference to water pollution, did not mention the importance of this factor.

Nor has this factor been considered of prime importance in toxicity work which did not relate directly to pollution problems. It is apparent, according to many published results, that the toxicity of some preparations decreases after the introduction of animals. (Bresslau, 1922, 1924; Duval, 1925; Carpenter, 1927; Drzewina and Bohn, 1928; Hubbs, 1930; Allee, 1931; Fowler, 1931.) It has also been shown that if the experiment is carried out with a small volume of preparation, the total quantity available to each fish is small in comparison with the quantity available in a large volume of the same concentration. The possibility then suggests itself that fish may live in the small volume but not in the large.

It is rather surprising to see the number of experimenters who have neglected this important point. For example, Powers (1917) took for granted that a volume of 1 liter was great enough to supply a constant quantity of poison during the experiment. Carpenter (1927), however, proved that Powers was wrong. Therefore we should not be surprised to find that different experimenters using the same concentrations report different results since they never concerned themselves greatly with the volume or flow of solution used.

The following experiments which were performed with DDT and derris powder show clearly the importance of the volume factor.

Experimental Conditions

The materials[1] used were as follows:

Derris Powder, Commercial (4.7 per cent rotenone); 12 per cent cube resin, 88 per cent inert matter.

A suspension of derris powder was prepared by weighing out 0.5 gram or 1.0 gram of commerical derris powder, and mixing thoroughly with 1000 or

[1] Derris was obtained from John Powell Co., DDT from Naugatuck Chemicals Ltd., Acetone from Chemicals Ltd., and Triton X-100 from P. M. Soden Chemicals.

3000 ml. of water. Desired dilutions were prepared by mixing a measured volume of the stock suspension (at least 100 ml.) with water, making subsequent dilutions as necessary. No stock suspension older than 3 hours was used.

DDT Technical, 72 per cent pp′, 20–25 per cent op′, 3–5 per cent other isomers; Acetone, commercial; Triton X–100, emulsifier.

A stock solution was prepared as follows; 1 gram DDT, 1 ml. Triton X-100 and acetone to obtain 100 ml. A suspension was made by mixing a measured volume of the stock solution (at least 1 ml.) with water. The desired concentration was obtained by subsequent dilutions, using a fresh suspension for each set of experiments.

In the experiments carried out at the University of Montreal, city water (pH 7.1) was used. A mixture of spring and lake water (pH 6.6), filtered through a Number 20 plankton net, was used at St. Faustin.

Sufficient oxygen was supplied to the fish by bubbling known quantities of air through the solution throughout the experiment. Above the biological minimum necessary to prevent asphyxiation, variations in the amount of air used with a given volume and concentration did not change the results obtained (see Table 1. Compare Experiment Number 862 with Numbers 846–848, 863, 865, 871–874.)

Glass jars or glass aquaria with iron frames were used. These containers are described in the tabulation shown below. The shape of the container, the exposed surface, and the depth of the suspension may have a certain influence on the survival of fish; in our experiments,

Volume of solution used, in liters	Shape of container	Total capacity (liters)	Surface in cm^2	Depth of solution
1 liter	Cylin. jar	3 liters	184	5.2 cm.
2 liters	Cylin. jar.	3 liters	184	10.4 cm.
3 liters	Cylin. jar	3 liters	184	15.6 cm.
5 liters	Cylin. jar	7 liters	250	20.0 cm.
5 liters	Rect. aquar.	9.5 liters	675	7.4 cm.
5 liters	Rect. aquar.	20 liters	1050	4.7 cm.
10 liters	Rect. aquar.	20 liters	1050	9.5 cm.
20 liters	Cylin. jar	82 liters	1520	13.2 cm.
20 liters	Rect. aquar.	40 liters	1260	15.9 cm.
20 liters	Rect. aquar.	65 liters	2300	8.7 cm.
40 liters	Cylin. jar	82 liters	1520	26.3 cm.
40 liters	Rect. aquar.	65 liters	2300	17.4 cm.
40 liters	Rect. aquar.	95 liters	2460	16.2 cm.

however, this influence seems to have no significance in the interpretation of our results.

The species used in these experiments included *Salvelinus fontinalis* (fingerlings from the St. Faustin Trout Hatchery), *Chrosomus eos, Ameiurus nebulosus, Catostomus catostomus* (taken from Lake Carré, St. Faustin). Size of fish and fasting time are given in the tables. These factors were not studied especially, and as the different lots of fishes were used in all volumes, the possible variations are balanced.

EXPERIMENTAL PROCEDURES

Five fishes were placed in the suspension prepared in each container. The time of death was recorded for each fish; dead fish were removed immediately. When 100 per cent mortality was not reached, the experiment was stopped after 48 hours for derris, and after 100 hours for DDT. Two experiments using 100 fishes in 20 liters were carried out for comparison with those using five fishes in one liter.

Controls which were run for each set of experiments did not show any particular weakness in the different lots of fishes. Mortality was more frequent in small volumes than in large, and occurred after a longer period (80 to 100 hours) than in the toxic suspensions due, probably, to pollution of the water on standing. The interest of these controls is minimized by the faet that the comparison is made between volumes, and no attempt is made to determine any minimum lethal concentration.

RESULTS

We have carried out 123 experiments involving 805 fishes with derris powder (Table 1), and 24 experiments involving 120 fishes with DDT (Table 2).

As may be seen in Tables 1 and 2, the percentage of mortality for a given concentration increases as the volume is increased. Similar results may therefore be obtained if data from experiments using a low concentration and a large volume are compared with data from experiments using a higher concentration and a smaller volume (see Table 3).

Time-Mortality Curves

Tables 1 and 2 give the results at the end of the experiments. As previously stated, most of the experiments were conducted with five fishes to each container. In many cases only one or two trials were made at a certain concentration and volume. The data from two experiments carried out at the same time and under the same conditions may appear quite different, as a result of variation in the susceptibility of individual fish to the poison. But when a series of experiments (adding three or four trials: 15–20 fishes) is compared with another series done under identical conditions, the data are similar, a better representation of the whole population being obtained. It is evident that the number five is too small to represent a population. Therefore, curves plotting percentage of mortality against time have been drawn only for *Salvelinus fontinalis* in derris powder suspension; in this case the number of individuals was considered sufficient to give a satisfactory representation of the population. To draw the curves, given in Figure 1, percentages were calculated from the total number of fishes submitted to identical

TABLE 1.—TOXICITY RESULTS OBTAINED WITH VARYING CONCENTRATIONS OF WHOLE DERRIS (4.7 PER CENT ROTENONE) AND VOLUMES, ACCORDING TO SPECIES*

Species	Concentration	Vol. in lit.	Aeration ml./min. liter	% Mortality in 48 hrs.	Average survival time in hours**	Temp. °C.	Number of experiments	Vol. of solution per fish (liters)	No. of fish	Experiment numbers	Date
Salvelinus fontinalis	1:20,000,000	1	50	*0*	48	18–21	3	0.2	15	835–37	11-28-46
		20	5	*61*	25	18–21	13	4.0	65	812–14, 816–19, 828–33	11-23 to 27-46
Av. length 102 mm.; av. weight 11.0 g.; fasting 3–24 days; city water.		40	2.5	*100*	7	18–21	6	8.0	30	789, 790, 809, 822, 823, 824	11-22 to 26-46
	1:15,000,000	1	50	*28*	38	18–21	7	0.2	35	838–40, 881–84	11-28 to 12-5-46
		20	5	*100*	6	18–21	3	4.0	15	879, 880, 904	12-5, 12-11-46
	1:10,000,000	1	50	*31*	38	18–21	16	0.2	80	841–43, 849–51, 860, 861, 866–69, 875–78	11-28 to 12-4-46
		20	50	*38*	32	18–21	1	0.2	100	864	12-3-46
		20	50	*100*	4	17–19	1	4.0	5	862	12-2-46
		20	5	*100*	4	18–21	9	4.0	45	846–48, 863, 865, 871–74	11-30 to 12-4-46
		1	50	*63*	20	18–21	7	0.2	35	854–59 918	12-2, 12-12-46
		20	5	*100*	1¾	18–21	4	4.0	20	917, 919–21	12-12, 12-13-46
	1:5,000,000	1	50	*2*	47	9	20	0.2	100	911	12-12-46
		20	50	*5*	46	9	1	0.2	100	910	12-12-46
		20	5	*100*	19	9	5	4.0	25	905, 912–15	12-11, 12-12-46

Chrosomus eos Av. length 2–3″; fasting?; natural water.	1:5,000,000	1	50	*0*	48	15–8	1	0.2	5	738	9-28-46
		3	16.6	*40*	36	15–8	1	0.6	5	739	9-28-46
		5	20	*60*	30	15–8	1	1.0	5	740	9-28-46
		10	10	*100*	12	15	1	2.0	5	741	9-28-46
		20	5	*80*	27	15	2	4.0	10	728–42	9-26, 28-46
	1:2,000,000	1	50	*100*	12	15	1	0.2	5	733	9-28-46
		3	16.6	*100*	8	15	1	0.6	5	734	9-28-46
		5	20	*100*	4¾	15	1	1.0	5	735	9-28-46
		10	10	*100*	10	15	1	2.0	5	736	9-28-46
		20	5	*100*	8	15	1	4.0	5	737	9-28-46
Ameiurus nebulosus Fasting?; natural water; ave. length 2″ in first series and 5″ in second.	1:1,000,000	1	50	*0*	48	15	2	0.2	10	597, 691	9-7, 20-46
		2	25	*100*	22	15.5	1	0.4	5	701	9-21-46
		3	16.6	*100*	17	14.5	1	0.6	5	692	9-20-46
		5	20	*100*	18	14.5	2	1.0	10	693, 694	9-20-46
		10	10	*100*	16	14.5–15.5	2	2.0	10	695, 702	9-20, 21-46
		20	5	*100*	15	14.5	1	4.0	5	696	9-20-46
	1:1,000,000	1	50	*0*	48	15–19	1	0.2	5	647	9-10-46
		10	10	*0*	48	15.5–20	1	2.0	5	703	9-21-46
		20	5	*100*	21	15	1	4.0	5	645	9-10-46
Catostomus catostomus Av. length 160 mm.; av. weight 35 g.; fasting?; natural water.	1:5,000,000	10	10	*20*	40	15	1	2.0	5	752	10-7-46
		20	5	*30*	46	15	2	4.0	10	751, 753	10-5, 7-46
		40	2.5	*100*	30	15	1	8.0	5	754	10-7-46
Total							123		805		

* Number of fish in each experiment 5, except in nos. 864 and 910.

** Average survival time was computed by adding individual survival times and dividing by total number of fishes; 48 hours was considered as the individual survival time for fishes still alive at end of experiment.

TABLE 2.—TOXICITY RESULTS OBTAINED WITH VARYING CONCENTRATIONS OF DDT-ACETONE-TRITON X-100 AND VOLUMES, ACCORDING TO SPECIES

Species	Concentration	Vol. in lit.	Aeration ml/min. liter	% Mortality in 100 hrs.	Average survival time in hrs.*	Temp. °C.	Number of experiments	Vol. of solution per fish (liters)	No. of fish	Experiment numbers	Date
Salvelinus fontinalis Length 3–4″; Fasting 3–35 days.	1:10,000,000	1	50	*0*	100	9	1	0.2	5	770	10-19-46
		3	17	*0*	100	9	1	0.6	5	771	10-19-46
		5	20	*20*	84	9	1	1.0	5	772	10-19-46
		10	10	*100*	34	9	1	2.0	5	773	10-19-46
		20	5	*100*	28	9, 17–22	2	4.0	10	774, 785	10-19, 23–46
		40	2.5	*100*	25	9	1	8.0	5	775	10-19-46
	1: 5,000,000	1	50	*25*	91	17–20	4	0.2	20	531–33	8-31-46
										543	10-19-46
		20	5	*100*	24	7–9	3	4.0	15	768–69	10-17, 18-46
										778	
Chrosomus eos Length 2–3″; Fasting?	1:10,000,000	3	17	*0*	100	11.5	1	0.6	5	763	10-15-46
		5	20	*0*	100	11.5	1	1.0	5	764	10-15-46
		10	10	*0*	100	11.5	1	2.0	5	765	10-15-45
		20	5	*0*	100	11.5	1	4.0	5	766	10-15-46
		40	2.5	*20*	89	11.5	1	8.0	5	767	10-15-46
	1: 5,000,000	1	50	*20*	82	13	2	0.2	10	755, 569	9-4, 10-9-46
		5	20	*40*	70	13	1	1.0	5	756	10-9-46
		10	10	*80*	38	13	1	2.0	5	757	10-9-46
		20	5	*100*	28	13	1	4.0	5	758	10-9-46
Total							24		120		

* Average survival time was computed by adding individual survival times and dividing by total number of fishes; 100 hours was considered the individual survival time for fishes still alive at end of experiment.

TABLE 3.—COMPARISON OF RESULTS WITH DIFFERENT CONCENTRATIONS

Toxic agent	Species	Concentration	Vol. in liters	Vol. of solution per fish	Per cent mortality	Time of survival for last dead in hours	Temperature °C.
Whole derris (4.7% rotenone)	*Salvelinus fontinalis* Av. length 102 mm.; av. weight 11.0 gms.; fasting 3–24 days; city water.	1:20,000,000	20	4.0	*61*	48	18–21
		1: 5,000,000	1	0.2	*63*	48	18–21
		1:20,000,000	40	8.0	*100*	11	18–21
		1:15,000,000	20	4.0	*100*	8	18–21
	Chrosomus eos Length 2–3″; fasting?; natural water.	1:10,000,000	20	4.0	*40*	70	13.5–12
		1: 5,000,000	3	0.6	*40*	70	15– 8
		1: 5,000,000	10	2.0	*100*	16	15
		1: 2,000,000	1	0.2	*100*	16	15
DDT (technical)	*Salvelinus fontinalis* Length 3–4″; fasting 3–32 days; natural water.	1:10,000,000	40	8.0	*100*	28	9
		1: 5,000,000	20	4.0	*100*	27	7– 9
	Chrosomus eos Length 2–3″; fasting?; natural water.	1:10,000,000	40	8.0	*20*	40	11.5
		1: 5,000,000	1	0.2	*20*	40	13

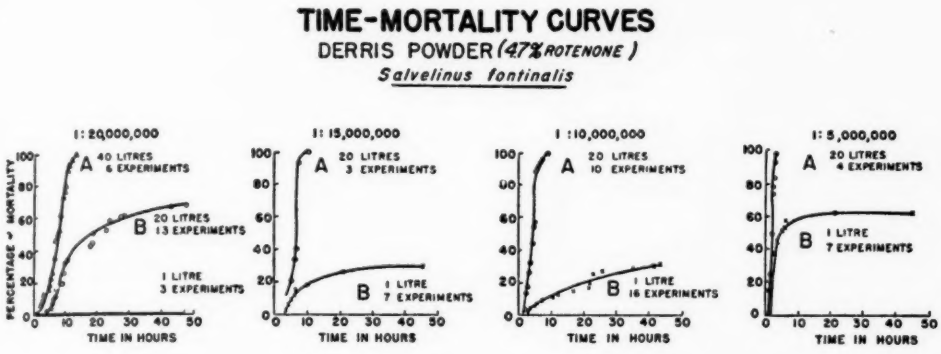

FIG. 1—Time-mortality curves for *Salvelinus fontinalis* in derris powder; comparison of different volumes in each of the following concentrations: 1:20,000,000; 1:15,000,000; 1:10,000,000; 1:5,000,000.

conditions of experimentation.

Regression Lines

Regression lines have been computed following the method proposed by Bliss, (1937).

When percentages of mortality are plotted against time, the curve is sigmoid in shape.

Bliss (1935a) assumes that the theoretical curve for percentage of mortality against individual susceptibility would show the shape characteristic of the cumulative normal curve of error, individual susceptibility being equated to the standard deviation σ. Statistical tables give the corresponding σ for any percentage of mortality. Since for percentages below 50, σ would be negative, the zero of the usual statistical table of deviates is equated to the digit 5 and the new statistical unit is called *Probit*. (For table of Probits, see Bliss 1935a.)

The reaction time, or a function of time, may be taken as an indirect measure of the individual susceptibility. Therefore, when the probits are plotted against a suitable function of time, a straight line is obtained. The suitable function of time may vary according to the action of the poison on fish, experimental process, reaction of the fish to the toxic agent, etc.

When 100 per cent mortality is obtained with derris powder, the reaction time plotted against probits is found to give a curve which is very close to a straight line. This may be due to the fact that there is no appreciable diminution in toxicity during the course of the experiment (see Figure 2).

However, when 100 per cent mortality is not reached, the reciprocal of reaction time is found to be the most suitable function. Here the reciprocal is used because as the experiment goes on the toxicity of the suspension gradually decreases (see Figure 3).

Statistical comparisons definitely show the importance of the factor *volume*, in the case of *Salvelinus fontinalis* in derris powder suspension. Although the data obtained with DDT are not sufficient to draw statistical curves, Table 2 is a good indication that volume is as important for DDT as for derris powder.

DISCUSSION

Since it has been demonstrated that the toxicity of some products decreases after the introduction of fish, and that it requires the use of many liters of solution per fish (8 liters to 1 fish, for example) to obtain reliable results on the lethal toxicity of a given concentration, the results published by Ginsburg (1945), Gersdorff (1930), Powers (1917), Odum and Sumerford (1946), Leonard (1938), Ellis (1937), and Embody et al. (1940), who used from one-half to three liters per fish, and results by Lackey and Steinle (1945), Wiebe (1930), and Smith (1939), who do not specify any volume of solution, may not be comparable in pharmacodynamy and not reliable in reference to pollution of natural waters, since these authors did not check the concentration at the end of their experiments and consequently did not know whether a quantity of poison sufficient to kill fish had been made available at a given concentration.

The disappearance of toxicity in a derris powder suspension after 48 hours, reported by Leonard (1938) is not an effect of time but is certainly related to the fact that the first two sets of fishes killed in the preparation had caused the toxicity to drop below the lethal point. A standing suspension kept in an aquarium for three days before the introduction of *Salvelinus fontinalis* proved to be as toxic as a fresh suspension, and possibly more so. (This fact confirms what has been noted in regard to poisoning lakes, Leonard (1938) pointing out that it is several weeks before toxicity disappears.)

Since the total quantity of poison, at a given concentration, is expressed by the volume in the case of standing preparations, and by the rate of flow in the case of running preparations, it is advisable to experiment with increasing volumes or rates of flow until an optimum is reached, above which results are identical. Any volume or rate of flow above the optimum may be used

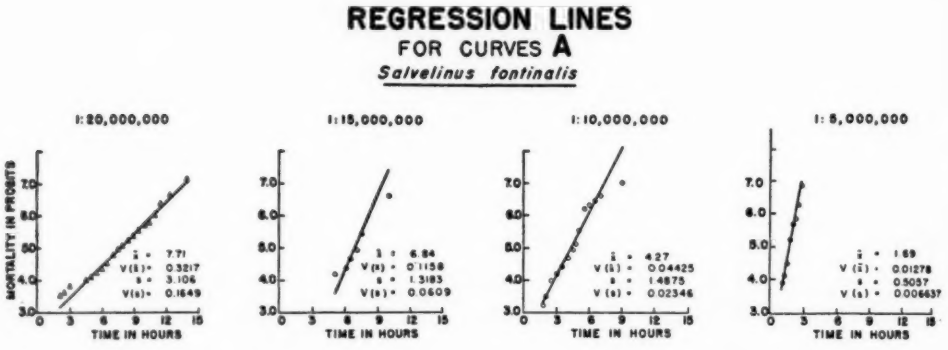

FIG. 2—Regression lines for curves A, Fig. 1, entire distribution. Definition of symbols:
x̄: average survival time, plotted at 5 probits.
V(x): variance of x̄.
s: standard deviation of the distribution: slope.
V(s): variance of s.

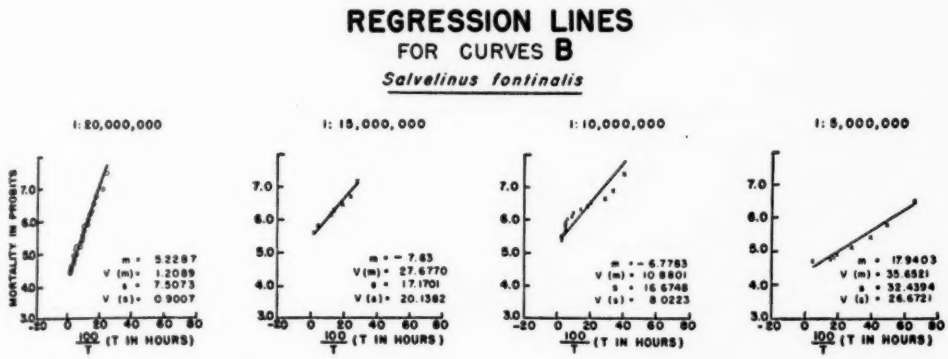

FIG. 3—Regression lines for curves B, Fig. 1, truncated distribution, truncation being at the lower end of the line. Definition of symbols:

m: hypothetical average rate of reaction 100/(time in hours) plotted at 5 probits.
V(m): variance of m.
s: standard deviation of the distribution:slope
V(s): variance of s.

for experimental purposes. If a factor changes (temperature, size of fish, composition of water, etc.) the optimum volume or rate of flow must be determined for the new conditions. This method is preferable even to a chemical determination of the concentration of the poison at the end of the experiment, as chemical determination does not take into consideration such factors as crowding reaction, individual susceptibility, and so on. Moreover, it is rather complicated to determine accurately the small quantities of DDT or rotenone such as are used in small concentration experiments.

CONCLUSION

To set up the most comparable and reliable tables for lethal concentration of products in which toxicity decreases after the introduction of fish or other aquatic animals, tables which can be applied to work in both pharmacodynamy and pollution, it is necessary to find the optimum volume or rate of flow of solution which gives reliable results. This optimum is easily found by use of increasing volumes or rates of flow until a series giving identical results is found.

If this method is adopted, results among experimenters will be more comparable and therefore more valuable. This method should help to clear away the misunderstandings and misinterpretations which arise from the wide variations in experimental procedures existing today.

To reach a complete standardization of the methods used in pollution research, many other factors besides volume or rate of flow must be controlled—the total length of time of the individual experiments, for example. For the present, however, we cannot suggest what this length of time should be, as there is such great variation in the rate of action of toxic products; some may require only a few hours, others many days. In the future, however, we hope to be able to suggest a solution to

this aspect of the problem. As to the number of fish in a container, it would probably be advisable to use only one fish, making as many duplicate trials as necessary to obtain a good representation of population, since aggregation may, as Allee (1931) suggests, have an effect on the behavior of fish during the experiments.

We wish to emphasize that this is only a preliminary study, to indicate the importance of the volume factor, and not an attempt to standardize methods at this time.

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VITAMIN A AS A SURVIVAL FACTOR OF THE BOBWHITE QUAIL (*Colinus v. virginianus*) IN OHIO DURING THE WINTER OF 1946–47[1]

Vincent Schultz

Ohio Cooperative Wildlife Research Unit, Columbus, Ohio

Introduction

The value of nutritional studies in the field of wildlife management has recently been brought to the attention of wildlife research workers by Nestler's studies (1946) on the vitamin A requirements of pen-raised bobwhite quail. His work demonstrates the need for comparative studies on wild birds.

Objectives and Methods of Study

The objectives of this study were to determine if possible (a) the role of vitamin A in the survival of Ohio bobwhites during the winter of 1946–47, and (b) whether or not periodic fluctuations in quail populations may result from a vitamin A deficiency as suggested by Nestler (1946).

Quantitative determinations of the vitamin A content of livers of wild bobwhite and the vitamin A activity content of four major quail foods, exposed during the winter, were made.

The state of Ohio can be divided into two major regions based on whether or not the area has been glaciated. The glaciated portion of Ohio is a region of flat to undulating terrain, of generally intensive farming and of relatively low quail populations, particularly in the western portion of the state. The unglaciated portion is a region of forested hills, of small farms, and of relatively high quail populations. This area comprises the extreme eastern and southeastern portions of the state.

Quail were collected from these two areas to determine if the known difference in population density might be accounted for by characteristics of the birds common to each region. A total of 62 specimens from the glaciated region and 52 specimens from the unglaciated region were collected for this study (Figure 1).

Promptly after collection either the livers (considered to be the principle storage organ of vitamin A) were removed from the birds and frozen or the birds were frozen intact until the livers could be removed. Upon removal, each liver was wrapped tightly in wax paper and frozen to avoid dehydration. At a later date a majority of the livers were sealed in nitrogen gas and replaced in a deep freeze unit until removal for analysis.

Vitamins A

Vitamins A are fat soluble vitamins of which only two forms, A and A_2, are

[1] This study was conducted by the writer while a research fellow of The Ohio Cooperative Wildlife Research Unit: The Ohio State University, The Ohio Division of Conservation and Natural Resources, The Fish and Wildlife Service and The Wildlife Management Institute cooperating. He is indebted to personnel of the Ohio Cooperative Wildlife Research Unit, Indiana Department of Conservation and The Patuxent Research Refuge, especially to C. A. Dambach, R. B. Nestler, J. B. DeWitt, R. B. Will, K. A. Mitchell, F. D. Haller, D. L. Leedy and E. L. Green.

definitely known to occur (Rosenberg, 1945). Both forms of vitamins A are known to be present only in animal organisms. Of the two, vitamin A is the only form of importance in this study, since vitamin A_2 has not as yet been observed in the tissues of mammals or birds. It has been isolated from fish (Rosenberg, 1945).

The rate and degree of absorption of vitamin A is dependent upon digestibility, fat, and tocopherol content of the food (Osier *et al.*, 1943). It is also affected by the presence of non-absorbable oils (Osier *et al.*, 1943). Fat soluble vitamins require the presence of bile and apparently also of pancreatic lipase for proper absorption (Rosenberg, 1945.

Vitamin A is not "stored" during periods of low vitamin A intake but rapidly accumulates in the liver when optimal doses are administered. With an intake of vitamin A in excess of the physiological needs the efficiency of "storage" decreases. Accumulated vitamin A is used rapidly when the intake is low. This rapid use is continued until an apparent critical level is reached in the liver. Thereafter, depletion is much slower (Rosenberg, 1945). Al-

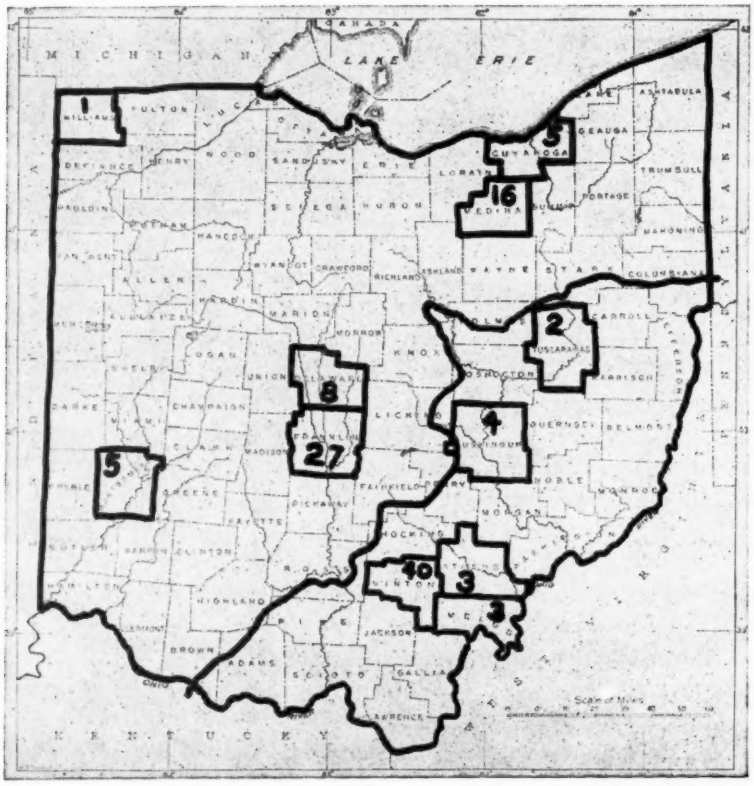

FIG. 1.—Distribution of specimens of bobwhite quail collected in Ohio.

though vitamin A is present in fairly large amounts in other glandular organs, the liver appears to be the major "storage" organ. This is the organ which was analyzed for its vitamin A content in this study.

PRO-VITAMINS A

Vitamin A is chemically a degradation product of certain carotinoids. The compounds in plants that possess vitamin A activity (precursors of vitamin A) belong to the class of carotinoids with forty carbon atoms. The nine naturally occurring compounds known to possess this activity are: alpha-carotene, beta-carotene, gamma-carotene, cryptoxanthin, echinenone, myxoxanthin, leprotene, aphanin, and aphanicin (Rosenberg, 1945). Of these, only four are probably available to the bobwhite quail: alpha-carotene, beta-carotene, gamma-carotene, and cryptoxanthin. The other known precursors of vitamin A were isolated as follows: leprotene from bacilli; echinenone from sea urchins; myxoxanthin from algae of the class Myxophyceae; aphanin from blue-green algae of the Aphanizamenon family; and aphanicin, which occurs together with aphanin. Beta-carotene appears to be the major source of pro-vitamin A in the bobwhite's diet. This assumption is based upon:

(a) The relative unavailability (with the exception of cryptoxanthin in yellow corn) and the low potency of other precursors.
(b) The relative abundance of beta-carotene.
(c) The high potency of beta-carotene.

The synthesis of pro-vitamins A is a process that appears to be catalyzed by light (Rosenberg, 1945). Other factors such as the chemical characteristics of the soil (Wynd and Noggle, 1946; Michael, 1943), geno-type of the species (Fraps, 1931), drought and heat (Beck, 1943), and increasing maturity (Kramer *et al.* 1945) play a part in determining the carotene content of plants.

Experimental evidence indicates that the vitamin A absorption mechanism of birds does not function as does that of other animals. It appears that birds need an external supply of fat for proper utilization of carotenes, although such fat apparently is unnecessary for the absorption of vitamin A (Rosenberg, 1945). Efficiency in the utilization of pro-vitamins is known to vary between species. It is also affected by other factors, such as the physiological condition of the individual. Under normal conditions the pro-vitamins A are not converted quantitatively into vitamin A. Usually the organism obtains much more of the precursors of vitamin A than are necessary for proper body function; the excess amounts are metabolized. Large quantities of pro-vitamins are less efficiently utilized than are smaller quantities (Rosenberg, 1945).

METHODS OF QUANTITATIVE ANALYSIS

Although various methods for quantitative determinations of vitamin A and of carotene are known, they all indicate relative rather than actual quantities; therefore, the selection of the quantitative method to be used in comparative studies is of the utmost importance. The methods of analysis for vitamin A and for carotene determinations used in this study were the identical physical methods applied in

vitamin A research at the Patuxent Research Refuge.[2] All analyses conducted there by the writer were under the supervision of Dr. J. B. DeWitt, head chemist. The methods of analysis used both in the vitamin A and the carotene determinations consisted primarily of (a) a phasic separation of the substance desired from interfering substances; (b) re-extraction; (c) a chromatographic procedure (omitted in some vitamin A determinations) and, (d) a determination of the optical density and the absorption curve of the final extract with a Bechman spectrophotometer.

Vitamin A and carotenoids possess typical absorption bands. One absorption band in the near ultraviolet is characteristic of vitamin A. The vitamin A absorption curve is a nearly symmetrical band with the coefficients falling away to a low value on either side of the maximum peak at 328 mu (millimicrons). With oxidation of the vitamin A there is a tendency towards an upward swing at the left end of the curve (Osier *et al.*, 1943, 1945). The typical vitamin A curve generally obtained during the analyses, the fact that there is little distortion at the maximum due to oxidation, and the results of Miyauchi and Sanford's studies (1947) on the effect of storage on the vitamin A content of grayfish livers has led the writer to believe that the method of storing the livers used during the period of collection was satisfactory. The specifications followed in determining whether or not a typical vitamin A curve existed before chromatographing were those used at The Patuxent Research Refuge:

$$\frac{E^{3}\ 300\ mu}{E\ 325\ mu} = 0.75 \text{ or less}$$

$$\frac{E\ 350\ mu}{E\ 325\ mu} = \text{between } 0.58 \text{ and } 0.68$$

If the spectrophotometric measurements made during the analysis did not fulfill these specifications, the solution was chromatographed.

A typical beta-carotene curve has a maximum peak of 450 mu. All extracts of carotene were chromatographed and the optical density was determined only at this maximum.

By means of suitable formulae the International Units (I.U.) of vitamin A per unit of substance were computed.

It is believed that the selection of the identical method of analysis used at The Patuxent Research Refuge provided data that are comparable, within the limits of this experiment, with Nestler's research.

RESULTS AND DISCUSSION

Body Weight—The relationship of vitamin A requirement to body weight is important. Studies on domestic fowl (Ewing, 1941) have shown that the larger the bird the greater are its vitamin A requirements. The results of a vitamin A study of birds in which no reference to body weight is made therefore appears to have limited usage and may at times be misleading. Figure 2 shows the frequency distribution of the body weights of birds collected from the two regions. The birds collected in glaciated Ohio were very significantly

[2] U. S. Fish and Wildlife Service, Department of the Interior, Laurel, Maryland.

[3] E = unit of absorption at different wave lengths (extinction coefficient).

larger ($t > t_{.01}$) than those collected in unglaciated Ohio. There was no significant difference in weight between the sexes from glaciated Ohio. The males collected in unglaciated Ohio were, however, significantly larger ($t_{.01} < t > t_{.05}$) than the females from that region. When all the males were compared with all the females a very significant difference occurred—the males being larger than the females. The difference in weight between birds from the two regions may play a role in "regional selectivity" during a possible period of vitamin A deficiency.

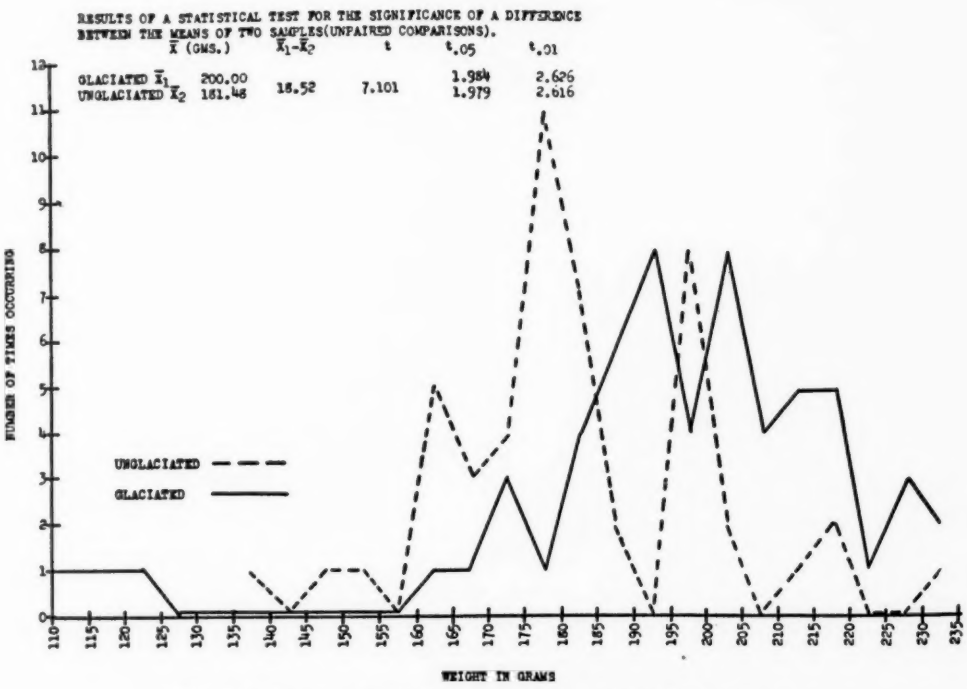
RESULTS OF A STATISTICAL TEST FOR THE SIGNIFICANCE OF A DIFFERENCE BETWEEN THE MEANS OF TWO SAMPLES(UNPAIRED COMPARISONS).
$\bar{X}$ (GMS.) $\bar{X}_1-\bar{X}_2$ t $t_{.05}$ $t_{.01}$
GLACIATED $\bar{X}_1$ 200.00
UNGLACIATED $\bar{X}_2$ 161.48 18.52 7.101 1.984 2.626
1.979 2.616
NUMBER OF TIMES OCCURRING
UNGLACIATED
GLACIATED
WEIGHT IN GRAMS

FIG. 2.—Frequency distribution of body weights by locality.

Liver Weight. It is possible that an increased vitamin A requirement, due to an increase in body weight, may be compensated for by an increase in liver weight. A large liver might indicate a greater storage capacity or a more complete utilization above a certain vitamin A intake than in a smaller liver. Figure 3 shows the frequency distribution of the liver weights of birds collected in glaciated and in unglaciated Ohio. Specimens collected in the glaciated region had very significantly larger livers than those collected in the unglaciated portion of the state. There was no significant difference in the liver weight between the males and the females in either region.

Correlation of Liver Weight to Body Weight (minus liver weight). The idea has been presented that the effects of an increase in liver weight may compensate for the higher vitamin A re-

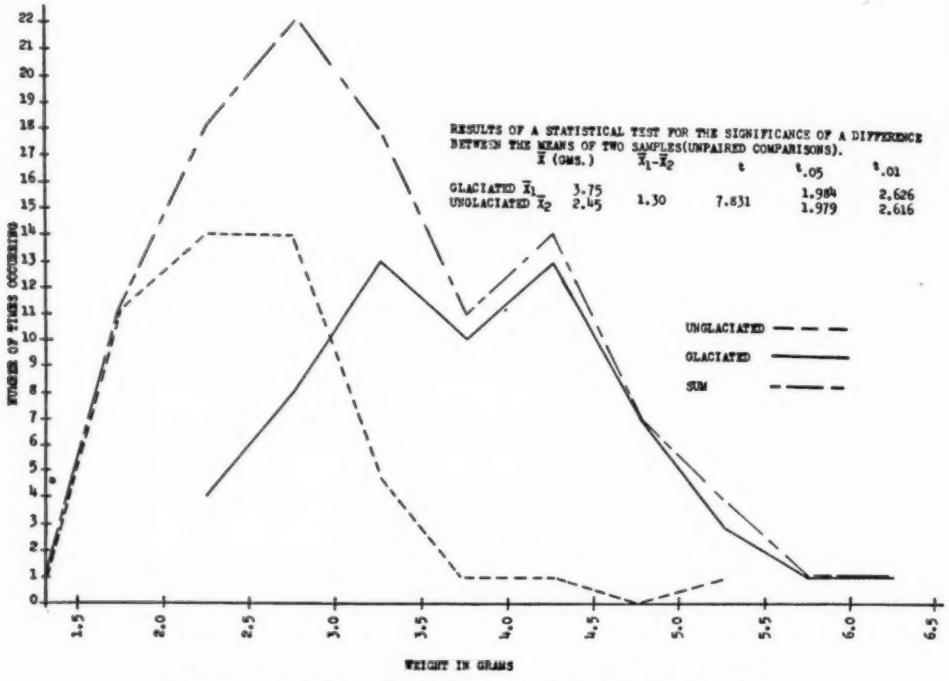
RESULTS OF A STATISTICAL TEST FOR THE SIGNIFICANCE OF A DIFFERENCE BETWEEN THE MEANS OF TWO SAMPLES(UNPAIRED COMPARISONS).
$\bar{X}$ (GMS.) $\bar{X}_1-\bar{X}_2$ t $t_{.05}$ $t_{.01}$
GLACIATED $\bar{X}_1$ 3.75 1.30 7.831 1.984 2.626
UNGLACIATED $\bar{X}_2$ 2.45 1.979 2.616
UNGLACIATED
GLACIATED
SUM
NUMBER OF TIMES OCCURRING
WEIGHT IN GRAMS

FIG. 3.—Frequency distribution of liver weight by locality.

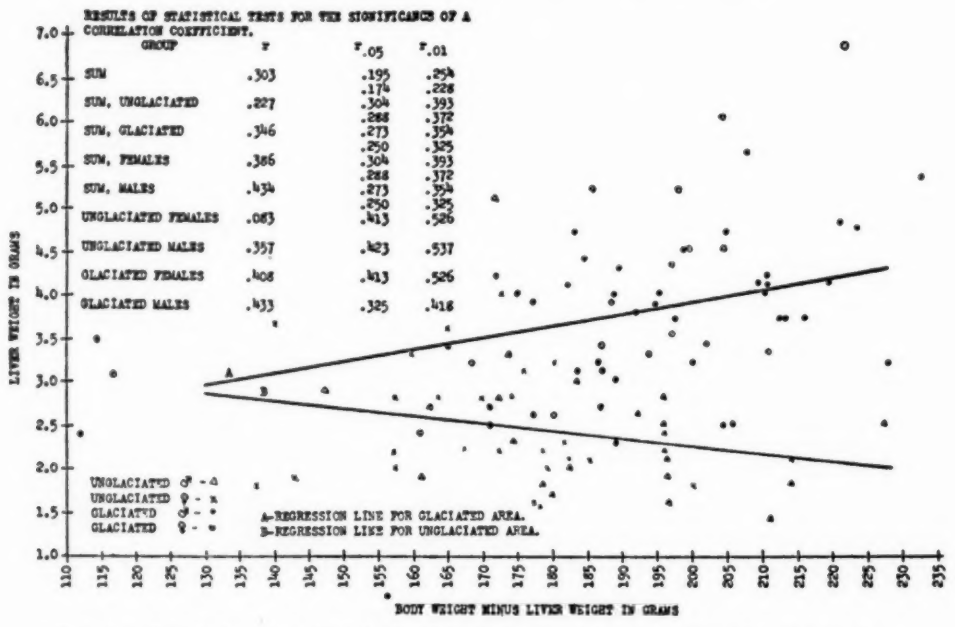
RESULTS OF STATISTICAL TESTS FOR THE SIGNIFICANCE OF A CORRELATION COEFFICIENT.
GROUP r $r_{.05}$ $r_{.01}$
SUM .303 .195 .254
SUM, UNGLACIATED .227 .174 .228
.304 .393
SUM, GLACIATED .346 .268 .372
.273 .354
.250 .325
SUM, FEMALES .386 .304 .393
SUM, MALES .434 .288 .372
.273 .354
.250 .325
UNGLACIATED FEMALES .083 .413 .526
UNGLACIATED MALES .357 .423 .537
GLACIATED FEMALES .408 .413 .526
GLACIATED MALES .433 .325 .418
UNGLACIATED ♂ - Δ
UNGLACIATED ♀ - x
GLACIATED ♂ - •
GLACIATED ♀ - •
A-REGRESSION LINE FOR GLACIATED AREA.
B-REGRESSION LIKE FOR UNGLACIATED AREA.
LIVER WEIGHT IN GRAMS
BODY WEIGHT MINUS LIVER WEIGHT IN GRAMS

FIG. 4.—Graph showing the relationship of liver weight to body weight by locality and sex. Body weight equals total weight less liver weight.

quirements of larger birds. The question necessarily follows as to whether or not there exists a relationship between liver weight and body weight; *i.e.*, is a large liver indicative of a large bird? This relationship was tested statistically by solving for the significance of a correlation coefficient. In bobwhite from glaciated Ohio a significant positive correlation existed; *i.e.*, an increase in body weight was accompanied by an increase in liver weight (Figure 4). This correlation was not found to hold in the birds collected in unglaciated Ohio. With the exception of the males from glaciated Ohio, no significant correlation was found in relation to the sexes.

Other factors remaining constant, it might be inferred that if a larger liver is indicative of a greater vitamin A storage, birds in glaciated Ohio are capable of a higher storage level than are birds from unglaciated Ohio. However, such variabilities as physiological utilization, foods available, chemical composition of foods and food predilections must also be considered.

I.U. of Vitamin A per Gram of Liver Weight. A study based on the I.U. of vitamin A per gram of liver weight rather than on total vitamin A storage may be misleading when comparing storage in individuals. It appears fairly evident that a deficiency based only on a per gram basis is of little value. In fact, it is doubted by the writer whether a practical standard can be established on a per gram basis alone due to variability of liver weight, body weight, and other factors.

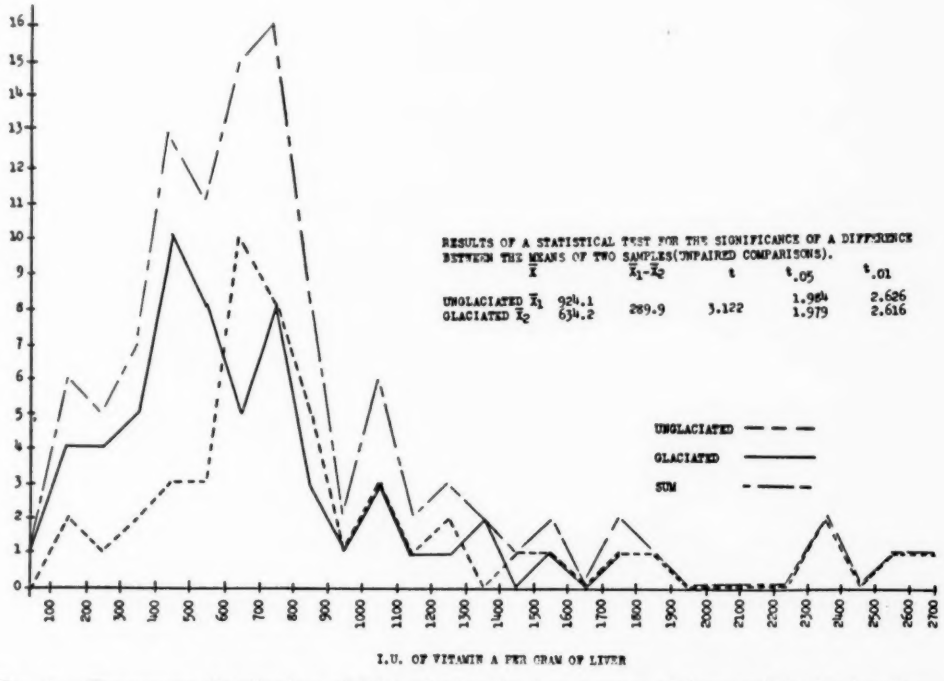
RESULTS OF A STATISTICAL TEST FOR THE SIGNIFICANCE OF A DIFFERENCE BETWEEN THE MEANS OF TWO SAMPLES(UNPAIRED COMPARISONS).
$\bar{X}$ $\bar{X}_1-\bar{X}_2$ t $t_{.05}$ $t_{.01}$
UNGLACIATED $\bar{X}_1$ 924.1 1.984 2.626
GLACIATED $\bar{X}_2$ 634.2 289.9 3.122 1.979 2.616
UNGLACIATED
GLACIATED
SUM
I.U. OF VITAMIN A PER GRAM OF LIVER

FIG. 5.—Frequency distribution of I.U. of vitamin A per gram of liver weight by locality.

A very significant difference occurred in the I.U. of vitamin A stored per gram of liver weight by bobwhite from the two regions (Figure 5). The birds collected in unglaciated Ohio were found to have stored more per gram of liver weight than did those birds from glaciated Ohio. This difference was not evident between sexes of the same region.

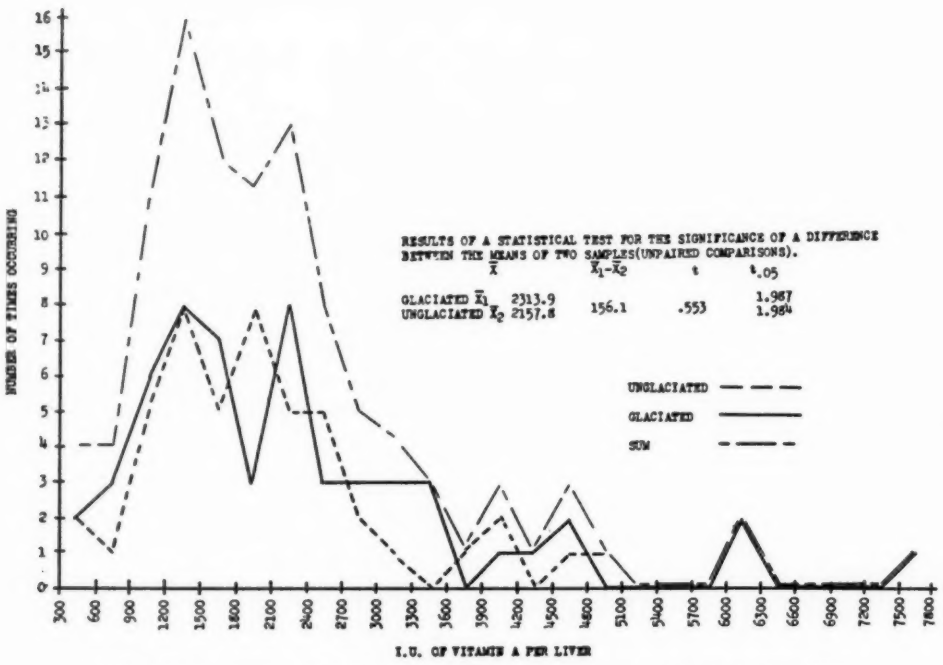
RESULTS OF A STATISTICAL TEST FOR THE SIGNIFICANCE OF A DIFFERENCE BETWEEN THE MEANS OF TWO SAMPLES(UNPAIRED COMPARISONS).
$\bar{X}$ $\bar{X}_1-\bar{X}_2$ t $t_{.05}$
GLACIATED $\bar{X}_1$ 2313.9 156.1 .553 1.987
UNGLACIATED $\bar{X}_2$ 2157.8 1.984
UNGLACIATED
GLACIATED
SUM
NUMBER OF TIMES OCCURRING
I.U. OF VITAMIN A PER LIVER

FIG. 6.—Frequency distribution of I.U. of vitamin A per liver by locality.

Although its value as a basis for determining survival in relation to vitamin A storage is questionable, less than 100 I. U. of vitamin A per gram of liver weight was considered as being indicative of a vitamin A deficiency (no external vitamin A deficiency symptoms visible). This approximate value is based on the amount of vitamin A stored by bobwhite on a maintenance diet of 2,500 I. U. of vitamin A per pound of feed, a diet of maximum egg production as determined by Nestler (1946). Based on this value only one of the birds examined was considered vitamin A deficient. Its storage was 80 I. U. of vitamin A per gram of liver weight. Vitamin A was not detected in three specimens. These three specimens were eliminated from the deficiency comparison, as a negative result in the analysis does not prove that vitamin A was not present, in either large or small amounts.

I. U. of Vitamin A per Liver. When comparisons on a total liver storage basis were made between the two regions no significant difference oc-

curred (Figure 6). The females from glaciated Ohio had significantly more vitamin A stored than did the males from this region. No such difference occurred in birds collected from unglaciated Ohio. The apparent significance of these data lies in the fact that although the larger birds from the glaciated region possibly require more vitamin A than do the smaller birds from the unglaciated section of the state, they did not store more vitamin A on a total basis. It might be presumed that if a vitamin A deficiency occurred the birds form the glaciated region would succumb before those from the unglaciated region.

Average Monthly Distribution of Vitamin A. The general trend in the vitamin A storage during the period of this study presented a difficult problem of analysis due to the many variables present. In the statistical analysis the average monthly amount of vitamin A present per gram of liver weight and per liver was compared as to sex and to region. The data were analyzed statistically by the method of group comparison and for the significance of a regression coefficient (Figure 7a and b). The method of group comparisons was used to test for a significant difference in the amount of vitamin A present in the livers of the bobwhite collected each month, groups being composed of birds of the same sex or from the same region. The significance of a regression coefficient was computed for each group through the month of January. The errors introduced by this method are

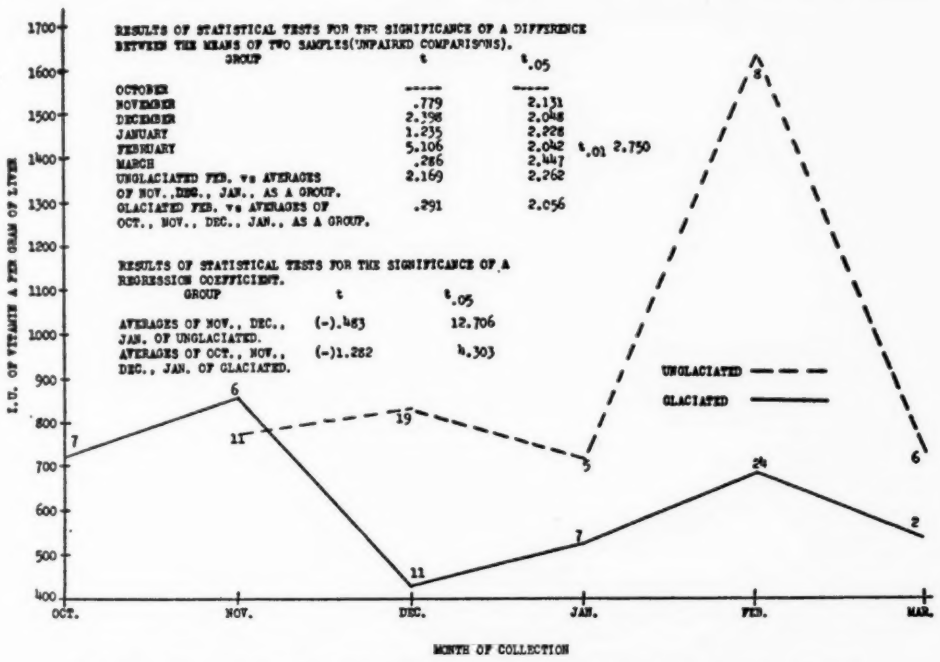

FIG. 7a. Monthly distribution of the average amount of I.U. of vitamin A per gram of liver weight by locality.

evident, but an indication of a general trend might be drawn. Assuming a linear relationship between the time of collection and the vitamin A content, there was no indication of a general trend other than horizontal in the vitamin A content of the livers of birds of either sex or from either region. Any monthly variation that might occur is possibly related to factors other than time, such as monthly variation in available vitamin A or its precursors. Differences existed between the sexes in February. This difference is probably the result of a select group of females collected from the same locality and therefore probably presents a skewed picture.

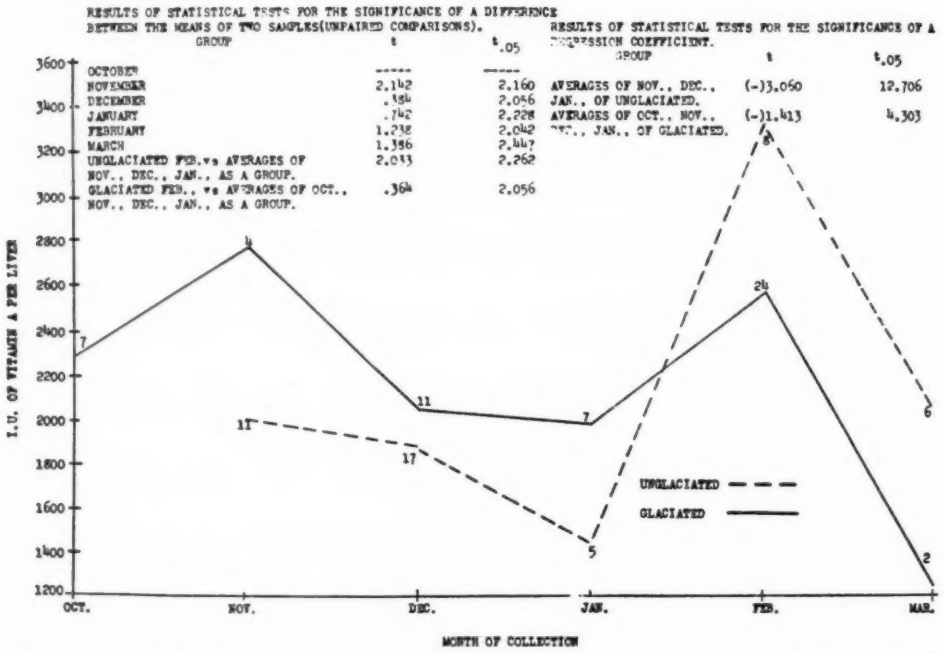

FIG. 7b. Monthly distribution of the average amount of I.U. of vitamin A per liver by locality.

The variability in the amount of vitamin A stored may be the result of physiological differences or differences in food predilection. If a period of vitamin A deficiency should occur in bobwhite quail populations, variations between individuals may play a selective role. However, reports of what were presumed to be individuals of complete coveys freezing to death, during approximately the same period of time, indicates that no selective process related to a vitamin A deficiency existed between individuals of the same covey.

Covey Studies. The preceding results indicate that sexual and regional differences in liver weight, body weight and vitamin A storage occur in Ohio bobwhite. The collection and analysis of what appeared to be complete isolated coveys within a relatively short period of time showed that variations existed

at the time of freezing. Due to variability in the amount of vitamin A stored by individuals, it might be presumed that a vitamin A deficiency is not the direct cause of death in some cases during complete freezing of coveys, providing that not all the variations in vitamin A storage are present at a deficient level.

Analysis of a covey of quail found frozen to death in a trap in Indiana indicates that death may occur without a vitamin A deficiency occurring (based on Nestler's data), probably the result of excess activity and exposure.

Results of Seed Exposure Tests. The determination of the periodic beta-carotene content of staple quail foods exposed in central Ohio during January, February, and March, 1947 presented a limited means of studying the effect of weather on the vitamin A activity

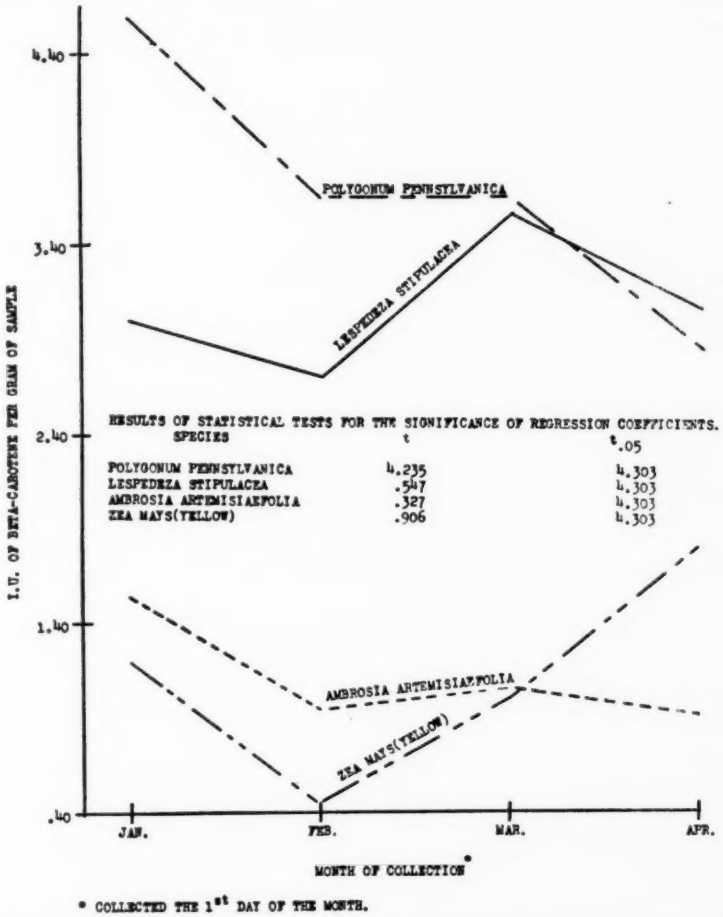

FIG. 8.—Periodic beta-carotene content of quail foods exposed in central Ohio during January, February, and March, 1947.

content of these seeds. The seeds exposed were *Polygonum pennsylvanicum*, *Lespedeza stipulacea*, *Ambrosia artemisiaefolia*[4] and *Zea mays* (Figure 8). Assuming a linear relationship between the time of exposure and the beta-carotene content, there was no indication of a trend other than horizontal. The variation in the monthly vitamin A activity content that may have existed was probably related to some other factor than time, possibly to certain weather conditions. The pre-exposure history of the seed may have had an influence on the results of the experiment.

General Statements

(1) The body weights and the liver weights of quail collected in glaciated Ohio were very significantly larger than the body weights and the liver weights of quail collected in unglaciated Ohio.

(2) A direct relationship of liver weight to body weight existed in birds collected in glaciated Ohio. This relationship was not evident in birds collected in unglaciated Ohio.

(3) The total amount of vitamin A stored by individuals from the two regions did not differ significantly. A very significant difference existed when the data were analyzed on a per gram of liver weight basis.

(4) The results of this study seem to indicate that vitamin A "fitness" should be determined on a per liver basis rather than on a per gram basis and that other variables, such as body weight, should also be taken into consideration.

(5) Based on monthly averages there appeared to be no indication of a general trend other than horizontal in vitamin A storage (assuming a linear relationship with time of collection). No constant difference existed monthly between sexes or regions.

(6) Individual variations in liver weight, body weight, and vitamin A storage existed in individuals of the same covey.

(7) The vitamin A activity of four major quail foods exposed to the elements showed no linear relationship to time.

(8) A vitamin A deficiency did not appear to be a limiting factor of bobwhite quail during the winter of 1946–47 in Ohio.

(9) A vitamin A deficiency can exist in wild animals as shown by reports of vitamin A deficient waterfowl in Sweden (Notini, 1941). This study is only a step forward towards determining the role of vitamin A in the survival of Ohio bobwhite, as the study was conducted during a relatively mild winter in Ohio.

[4] Britton and Brown.

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SOME PROTOZOAN PARASITES OF THE EASTERN WILD TURKEY IN PENNSYLVANIA[1]

Edward L. Kozicky[2]

Department of Zoology and Entomology, The Pennsylvania State College

During the course of an investigation on the life history and management of the eastern wild turkey (*Meleagris gallopavo silvestris* Vieillot) in Pennsylvania from September 1941 to October 1943 and from September 1946 to September 1947, a field study was made on the prevalence of parasites and diseases in the species. The species of protozoa encountered were *Eimeria meleagridis*, which causes coccidiosis, *Leucocytozoon smithi*, *Haemoproteus* sp., *Histomonas meleagridis*, which causes blackhead or infection enterohepatitis, and *Trichomonas* sp., the causative agent of trichomoniasis.

A State-wide survey for the presence of coccidiosis was made in conjunction with other field work and a total of 95 droppings were collected from nine different counties during all seasons of the year. The droppings were preserved in five per cent formalin and later examined in the laboratory. A standardized technique was used for concentrating oocysts as outlined by Cable (1940, p. 77).

Table 1 shows the county and the number of positive and negative specimens analyzed. The 95 fecal samples showed a 40.0 per cent infection. However, a higher percentage of native wild turkeys probably are infected as the bird may not discharge the oocysts in every dropping. Dr. E. A. Allen, United States Bureau of Animal In-

[1] Paper No. 48 from the Pennsylvania Cooperative Wildlife Research Unit; Fish and Wildlife Service, The Pennsylvania State College, Pennsylvania Game Commission, and the Wildlife Management Institute, cooperating. Authorized for publication on November 18, 1947 as Paper No. 1407 in the journal series of the Pennsylvania Agricultural Experiment Station.

[2] Graduate Assistant, Department of Zoology and Entomology, The Pennsylvania State College. Dr. E. P. Johnson aided the writer by editing the technical data of this paper.

TABLE 1.—DISTRIBUTION BY COUNTY OF COCCIDIAL OOCYSTS IN NATIVE WILD TURKEY DROPPINGS IN PENNSYLVANIA

County	Positive samples	Negative samples	Total
Centre	8	10	18
Huntingdon	12	28	40
Fulton	1	3	4
Blair	2	0	2
Bedford	1	4	5
Potter	1	0	1
Mifflin	0	3	3
Clinton	6	7	13
Cameron	7	2	9
	38	57	95

dustry, identified the species of coccidia as *Eimeria meleagridis*. Coccidiosis has been the cause of severe mortality in young captivity-reared turkey poults less than eight weeks old, and the disease has been the greatest single cause of mortality in young turkeys at the Pennsylvania wild turkey farm. The use of sulfa drugs, however, has practically eliminated any high losses from coccidiosis at the farm. Mosby and Handley (1943, p. 139), mention an outbreak in young captivity-reared poults in 1938. Blakely (1937, p. 16) and Shillinger and Morley (1937, p. 15) also found coccidiosis in captivity-reared wild turkeys.

Although coccidiosis produces a high mortality rate under game farm conditions, its toll in the wild still remains to be determined. No apparent seasonal distribution of coccidial oocysts was noted.

Leucocytozoon smithi was found to be rather prevalent in wild turkeys in Pennsylvania. Four different tests, involving 92 game farm-reared and 5 native wild turkeys, were conducted. All blood smears were stained with Wright's stain as outlined by Coffin (1945, p. 247).

Table 2 shows that 20.7 per cent of the 92 game farm-reared wild turkeys were infected, and all five native wild turkeys were hosts of the protozoan parasite. The increase of incidence at the Pennsylvania wild turkey farm in Lycoming County from April 7 to September 14, 1947, may be related to the seasonal distribution of the blood protozoan as shown by Johnson (1942, p. 216). All five native wild turkeys showed a larger number of parasites than the captivity-reared birds. Table 2 also shows that there may be a geographical distribution of the parasite in Pennsylvania; that is, the protozoan is more prevalent in the southern than

TABLE 2.—PREVALENCE OF LEUCOCYTOZOON IN 92 CAPTIVITY-REARED AND 5 NATIVE WILD TURKEYS

Date	County	Captivity-reared wild turkeys	No. Infected	% Infected	Native wild turkeys	No. Infected	% Infected
4- 7-47	Lycoming*	50	0	*0.0*			
6-11-47	Huntingdon	9	5	*55.6*	1	1	*100.0*
7-31-47	Fulton	9	9	*100.0*	4	4	*100.0*
9-14-47	Lycoming*	24	5	*20.8*			
		92	19	*20.7*	5	5	*100.0*

* Pennsylvania wild turkey game farm.

in the northern section of the Pennsylvania wild turkey range. The identification of this parasite was confirmed by Dr. E. P. Johnson, Animal Pathologist, Virginia Agricultural Experiment Station.

Mosby and Handley (1943, p. 141) found an average of 40.0 per cent infection in 268 birds (40 domestic, 183 captivity-reared, and 45 wild turkeys). Johnson (1938, p. 649) recognized the presence of this protozoan parasite in domestic turkeys in Virginia and discovered that it has caused losses of 10 to 50 per cent in domestic turkeys in that state. Wehr and Coburn (1943) noted *Leucocytozoon* sp. in wild turkeys at the Pennsylvania wild turkey game farm. However, the pathogenicity of this blood protozoan parasite in wild turkeys has never been proven.

Haemoproteus sp., another blood protozoan parasite which causes a malaria-like disease, was identified in five (5.2 per cent) out of 97 blood smears collected in 1947. The parasite was present in one adult native wild gobbler and in four captivity-reared wild turkey hens on June 11, 1947. The identification of this protozoan was checked by Dr. E. P. Johnson. Herman (1944, p. 97) lists a large number of bird species that are hosts for this parasite. Herman and Glading (1942, p. 152) found an 84.3 per cent infection in valley quail (*Lophortyx californica californica*) and an apparent seasonal fluctuation in infection.

O'Roke (1930, p. 44) states that the effect of *Haemoproteus lophortyx* on valley quail varies from apparent minor infections to those which are fatal. The effect of *Haemoproteus* sp. on native and captivity-reared wild turkeys is not known.

Blackhead or infectious enterohepatitis due to *Histomonas meleagridis* is considered the scourge of the domestic turkey industry and has been diagnosed as the cause of mortality in four native wild turkeys by the Pennsylvania Bureau of Animal Industry. Blackhead causes some annual mortality to turkeys at the Pennsylvania wild turkey farm. Unfortunately, there is no method of determining carriers or even infected birds in the wild unless the disease is in an acute stage, and the birds are promptly autopsied. Consequently, the prevalence of this protozoan disease is not known, although the pathogenicity of the parasite has been established for native wild turkeys.

Mosby and Handley (1943, p. 139) state that this disease has resulted in the death of an occasional poult and several adult turkeys from captive brood stock. Stoddard (1935, p. 329) points out that blackhead was the only disease noted by him among wild turkeys living a free wild life.

Trichomoniasis of the upper digestive tract was diagnosed as the probable cause of mortality in an adult native wild gobbler in the spring of 1947 by the Animal Pathology Laboratory of The Pennsylvania State College. Autopsy findings indicated the disease, but the causative agent, *Trichomonas* sp., was not isolated. Blakely (1937, p. 16) states that trichomoniasis has been found in captivity-reared wild turkeys.

SUMMARY

1. The eastern wild turkey in Pennsylvania is host to such known proto-

zoan parasites as *Eimeria meleagridis*, *Leucocytozoon smithi*, *Haemoproteus* sp., *Histomonas meleagridis*, and *Trichomonas* sp.

2. Coccidial oocysts were found in 38 (40 per cent) of the 95 native wild turkey fecal samples examined.

3. *Leucocytozoon smithi* was found in all five native wild turkeys examined and in 20.7 per cent of 92 captivity-reared wild turkeys.

4. *Haemoproteus* sp. was found in only five (5.2 per cent) of the 97 blood smears examined from native and captivity-reared wild turkeys.

5. Blackhead or infectious enterohepatitis has been diagnosed as the cause of mortality in four native wild turkeys in Pennsylvania.

6. The effect of any of these protozoan parasites on wild turkey population levels is not known.

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FACTORS IN WINTER STARVATION OF PHEASANTS[1]

H. Elliott McClure
Bakersfield, Cal.

Concurrent with observations on populations and natural production of pheasants (*Phasianus colchicus*) in Nebraska, birds were trapped each month during the winters from1941 to 1943 to ascertain their winter weights. While trapping at the Valentine National Wildlife Refuge the weather became severe during March 1943and pheasants began starving. This paper attempts to deal with some of the factors bringing about these starvation conditions.

Ring-necked pheasants were introduced or moved into the central-northern sandhills during the years just preceding 1925. Sandhill grasslands occupy over 22,000 square miles, or more than one-fourth of Nebraska's area. The birds became established in valleys and meadows near lakes and along streams. In some areas the population reached a density of approximately 90 birds per square mile. This is a low density compared with the 300 or 400 birds per section estimated for some other areas, and the Valentine region did not appear over populated. Earlier records are not available, but observations made by Dr. Ward M. Sharp (unpublished) determined that winter losses were not severe between 1935 and 1943. The Armistice Day storm of 1940 and the severe winter of 1935–36 did not appear to result in heavy pheasant losses.

[1] Work conducted under direction of the Nebraska Game, Forestation and Parks Commission, Paul T. Gilbert, Director.

Methods

The birds were caught in large funnel traps made of two- or four-inch wire mesh and measuring 15×8×6 feet, or in smaller traps, 6 feet square, 30 inches high, equipped with drop-wires to retain the birds. Neither type of trap was efficient until the birds became very hungry, even though locations were baited continuously for weeks previous to actual trapping. Five traps distributed along a ten-mile route were visited twice daily and while traveling from trap to trap the number of pheasants feeding on meadows was recorded. Any dead birds or remains were examined and crop contents collected. During mid-day, when the weather was not too severe, pheasant activities were observed from a panel truck used as a blind.

Pheasant Weights

Average monthly pheasant weights and the number of birds trapped are shown in Table 1. It is obvious from this table that in many cases too few birds were captured to give reliable evidence of changes in the weight of the general population. Pheasant trapping in the sandhills was subject to variable success, for the birds did not have access to field crops and were not attracted to grain baits unless the weather was cold and the ground covered with snow. Even though seven tons of grain were distributed at 35 feeding stations in 1942-43 the resulting catch was only a little over one thousand birds.

If we accept the data at hand, we

TABLE 1.—AVERAGE WEIGHT OF PHEASANTS TRAPPED EACH MONTH OF WINTERS OF 1942–1942 AND 1942–1943. THIS INCLUDES WEIGHTS OF BIRDS FOUND FRESHLY DEAD. WEIGHT GIVEN IN GRAMS

Month	Male				Female			
	Number		Weight		Number		Weight	
	1941–1942	1942–1943	1941–1942	1942–1943	1941–1942	1942–1943	1941–1942	1942–1943
Nov.		1		1418		3		1076
Dec.		43		1535		37		1081
Jan.	36	16	1502	1440	20	8	1076	1076
Feb.	6	482	1418	1393	6	382	1104	1022
Mar.	4	41	1474	1068	8	40	1048	908
Apr.	4	2	1362	1390	2	5	1048	1216
Total	50	585	1437	1384	36	475	1067	1059

find that the maximum average loss of weight in 1942, between January and April, was five ounces (140 grams) in the male and one ounce (28 grams) in the female. Between December, 1942, and the end of March, 1943, the average loss was 16.5 ounces (462 grams) per male and 6.2 ounces (174 grams) per female. In January, 1943, cocks had begun to lose weight, but hens had not. By the last week of February both sexes were losing weight. The average weight of males in December, 1942, was 3 pounds and 6.2 ounces (1,536 grams). By the end of February they had lost 9.6 per cent of their weight. By March 25, 1943 the average was down to 2 pounds 5.7 ounces (1,068 grams) or an average loss of 30.4 per cent. Hens weighed 2 pounds 6.2 ounces (1,082 grams) in December and had lost 5.7 per cent of their weight by the end of February. During March the average weight went down to 2 pounds (908 grams), a loss of 16.2 per cent. From March 22 to 27 many birds were so weak that they could not fly and could be caught by hand. Others could barely get into the air, and very few had found sufficient food to maintain their weight. Not only were there many deaths from the effects of weakness and cold, but even after the weather turned mild the weakened ones could not forage for food and died on the meadows or in their roosts. Dead birds were found on the meadows, and three of six birds caught by hand died at night while asleep even after having fed on grain.

POPULATION CHANGES

The average numbers of birds per mile of sandhill trails for the winter months of 1942 and 1943 are given in Table 2. The birds did not collect in numbers in the marshes in 1941–42 until January. Following severe Janu-

TABLE 2.—AVERAGE NUMBER OF BIRDS SEEN PER MILE OF REFUGE TRAILS EACH DAY ON VALENTINE WILDLIFE REFUGE DURING WINTER

Month	1941–42	1942–43
November	3.0	12.7
December	3.1	19.2
January	35.7	14.5
February	9.2	27.0
March	10.0	9.3
April	7.6	5.1
Average	11.4	14.6

ary weather they dispersed. In 1942–43 they aggregated in numbers in November and remained over December and January with the peak concentration in February.

The greatest numbers of birds counted in a day are given in Table 3. Emphasis is placed on highest numbers seen in one day, because under certain conditions the bulk of pheasants in a marsh will move onto meadows where they may be counted. From both methods it appeared that the population entering winter quarters was about 25 per cent less in 1943 than in 1942. The peak population of February 1943 was 30 per cent less than that of January 1942. The average trailside counts for these months showed a 24 per cent reduction in 1943. Early concentration in 1942–43 was attributed, in part at least, to colder weather. In March 1943 the highest number seen was 12 per cent less than for that month in 1942. Similarly the April 1943 peak was 16 per cent less than April 1942. Because of rapid shifts in pheasant numbers about the marshes, it was difficult to arrive at an estimate of the loss during March. However, tallies of the winter of 1943–44 showed effects of the winter before. The population had been reduced so low that following a normal breeding season, the peak count for the winter, in January of 1944, was only 29 per cent of that in 1942 and 68 per cent of that in 1943.

TABLE 3.—GREATEST NUMBER OF PHEASANTS SEEN IN ONE DAY EACH MONTH DURING WINTER AT VALENTINE WILDLIFE REFUGE

Month	1941–42	1942–43
November	166	663
December	160	1407
January	2460	1022
February	415	1705
March	792	699
April	314	262

PLANT-WEATHER-HABITAT COMPLEX

Records from the Valentine Weather station are shown in Table 4. November and December of 1942 were but two degrees colder than corresponding months in 1941. January 1943 was eight degrees colder than January 1942, but February of 1943 was 11 degrees warmer than that of 1942. Following the warm February, March turned severely cold with lowest recorded temperatures since March 1889. In spite of this, the mean winter temperature for 1942–43 was almost normal, while that of 1941–42 was four degrees above normal.

Observation of the utilization of native plants by pheasants was begun in 1938 by Dr. Sharp and was continued by the author until 1944. From this the nine most important winter foods for this region were established as: the seeds of the sandhill sunflower *Helianthus petiolaris*, smartweed *Polygonum ramocissimum*, and jewel weed *Impatiens nortonii;* the seeds and flowers of Russian thistle *Salsola pestifer;* the leaves of dandelion *Taraxacum*, clover *Melilotus*, and blue grass *Poa pratensis;* and the larvae of several species of flies of the genus *Bibio*. This diet may be further supplemented by duck potato *Sagittaria*, or by the seeds and fruit of a hundred species of plants.

The plant-weather complex involved in the availability of these staple foods is shown in Table 5. Sunflower was important mainly during the fall and early

TABLE 4.—WEATHER RECORDS FROM VALENTINE WEATHER STATION

	Nov.	Dec.	Jan.	Feb.	Mar.	Average or Total
Maximum temperature						
1942–42	82	72	57	53	67	66
1942–43	73	53	63	70	87	70
Minimum temperature						
1942–42	−6	−10	−23	−12	13	− 7.6
1942–43	1	−10	−24	− 3	−21	−11.4
Mean temperature						
1942–42	38.2	29.7	24.0	23.7	33.8*	30.0
1942–43	36.2	27.2	16.2	32.2	21.3	26.6
Normal temperature	34.6	24.6	18.9	21.4	32.3	26.4
Number days with snow on the ground.						
1942–42	10	14	9	17	20	70
1942–43	7	19	24	15	18	83
Total inches of snow						
1942–42	2.9	4.6	.7	9.7	15.6	33.5
1942–43	2.5	.7	5.9	2.1	12.4	25.6
Total precipitation in inches						
1941–42	.45	.48	.13	.97	1.96	3.99
1942–43	.28	.11	.31	.11	.73	1.54
Number of days with sleet						
1941–42	0	0	1	0	1	2
1942–43	0	0	0	0	1	1
Average wind velocity in miles per hour						
1941–42	8.3	9.2	9.0	7.0	11.1	8.9
1942–43	8.7	8.0	8.3	10.1	8.9	8.8

* Mean temperature for March, 1943, average of first 25 days.

winter months. It was harvested by redwings, grackles, goldfinches and other granivorous birds and rarely lasted longer than December. Smartweed was an important food in early winter, but was sometimes available for the whole season. The marsh inhabiting jewelweed was important during December and January. Dandelion leaves were eaten during November and December and their place was taken by the leaves of grass and clover later on. January and February appeared to be the most severe months, for then the birds gorged on Russian Thistle and grass. *Bibio* larve, which feed on decaying vegetation and aggregate in large groups beneath willow hummocks, were often important sustaining food during January, February and March. At this time pheasants have been found with more than a hundred cubic centimeters of such larvae in their crops.

The spring of 1942 was the wettest for several years. This raised lake levels and subsoil water to the highest point since 1932. Some lake surfaces nearly doubled in area and marshy shores were inundated. The fall of 1942 was dry, enough to parch plants, but not to materially lower the water levels in lakes and marshes. The effects of these two conditions were a reduction in both the growth and availability of the staple foods on low ground, and the stifling of seed production of the sunflower on uplands. Duck potato and other marsh plants occasionally used by the birds were under water. The meager crops of weed seeds were quickly harvested, and in October only 30 per cent of the sun-

TABLE 5.—THE PLANT-WEATHER COMPLEX OF 1942–43 EFFECTING AVAILABILITY OF STAPLE WINTER FOODS FOR PHEASANTS IN NEBRASKA SANDHILLS

Plant	Sandhill sunflower *Helianthus petiolaris*	Smartweed *Polygonum ramocissimum*	Jewelweed *Impatiens nortonii*	Russian thistle *Salsola pestifer*	Dandelion *Taraxacum*	Clover *Melilotus*	Blue Grass *Poa pratensis*	March flies *Bibio*
Part of plant used	Seeds	Seeds	Seeds	Seeds and flowers	Leaves	Leaves, seed and flowers	Blades and crowns	Larvae
When usually utilized	Fall, early winter	Early winter or all winter	Dec. and Jan.	Jan. and Feb.	Nov. and Dec.	Late winter	Late winter, spring	Jan. Feb. Mar.
Habitat location	Upland	Meadow and upland hollows	Marsh borders	Eroded or disturbed areas	Meadows	Meadows and uplands	Hay meadows	Willow thickets
Factors, effecting availability	Taken by redwings, goldfinches, etc.	Eaten by birds and mice	Fluctuation of water levels	Weather and aggressivness of native plants	Weather	Weather	Weather following mowing of meadows	Water level in marsh thickets
Effects of 1942 weather	Seed production reduced by fall drouth	Seed production reduced by fall drouth	Fewer plants following wet spring	Wet spring inhibited growth	Crop about normal	Crop about normal	Fall drouth inhibited succulent growth	Decreased by raise in water level
Availability during winter of 1942–43	Quickly utilized by migrating granivorous birds	Harvested by migrating birds	Almost no seeds produced	Present but buried under snow and ice	Present but buried under snow and ice	Present but buried under snow and ice	Present but buried under snow and ice	Not present in any numbers

flower heads remained with seeds. Because of the late drought, grass failed to produce the basal shoots commonly found green during winter. What happened to the *Bibio* larvae was not determined, but no birds were found that had eaten them.

SUMMARY

In 1943 pheasant winter mortality in Nebraska resulted from a combination of habitat and weather factors. Contributory factors extended beyond one growing season. The birds had been increasing in numbers during a period of drouth, 1938–1941, which extended marsh habitats by reducing lake surfaces and exposing more feeding area to the pheasants. When a radical reduction of marsh was coupled with low upland food production and extreme winter conditions of snow and cold the pheasants succumbed. Immediate cause of population losses was deep ice-covered snow with very low temperature. Contributory factors of weather and habitat changes contrived to reduce the bird to a condition more susceptible to cold and starvation. Stabilized water levels in the lakes might have prevented the mortality, artificial feeding did not.

EXPERIMENTAL FEEDING OF RING-NECKED PHEASANTS IN THE WILLAMETTE VALLEY, OREGON[1]

Hans G. Uhlig

West Virginia Conservation Commission, Elkins, West Virginia

This study of the food requirements of the ring-necked pheasants, *Phasianus colchicus torquatus* (Gmelin), was made during the period of November 2, 1946 to January 31, 1947 to determine the minimum winter food requirements of pheasants in the temperate portions of the Pacific Northwest. Data for the study were obtained from penned birds located at the Experimental Fur Farm, Oregon State College, Corvallis, Oregon.

General background for the study is as follows: Yearly censuses have shown that there had been considerable variation in the pheasant population from 1936 to the time this study was initiated. In 1946 the Willamette Valley had only 12 birds per 100 acres as compared to 28 per 100 habitat acres in 1942.[2] While a large percentage of this decrease has been attributed in some years to late spring rains, which limit the survival of young pheasant chicks, some individuals believe that, because of the relatively mild winters in western Oregon, pheasants should be sustained at higher densities than they are. It has been suggested also that many pheasants do not survive the winter because the nutritional value of available winter herbage is too low, due to leaching by excessive rainfall. Others are of the opinion that the food "factor" is not the cause of the pheasant depletion during the winter months, but place the blame on causes such as poaching, increased hunting pressure, predators and other depleting factors.

Separate studies made by Newcomb (1940) and Morse (1941) on Protection Island, which is located in the Strait of Juan de Fuca, Jefferson County, Washington, indicated that at certain critical periods during the winter pheasants exist on a high percentage of green herbage. Both men recommended experiments to determine whether pheasants could survive through winter on high percentages of green foods.

Objectives

With these recommendations in mind this study was undertaken with the following objectives: (1) To determine whether pheasants could survive on green herbage alone; (2) To determine whether the addition of weed seeds is required for survival; (3) To determine whether the addition of cereal grains such as wheat are required for survival; (4) To determine what proportions of the various food items are required for survival.

Method of Study

Fifty-five young birds about 12 weeks old were obtained from the Oregon State Game Farm at Corvallis on August 15, 1946. From this date until the

[1] The writer is indebted to Mr. Arthur S. Einarsen, Biologist of the Fish and Wildlife Service and leader of the Oregon Cooperative Wildlife Research Unit for his guidance throughout the experiment.

[2] Data from the files of the Oregon Cooperative Wildlife Research Unit, Corvallis, Oregon.

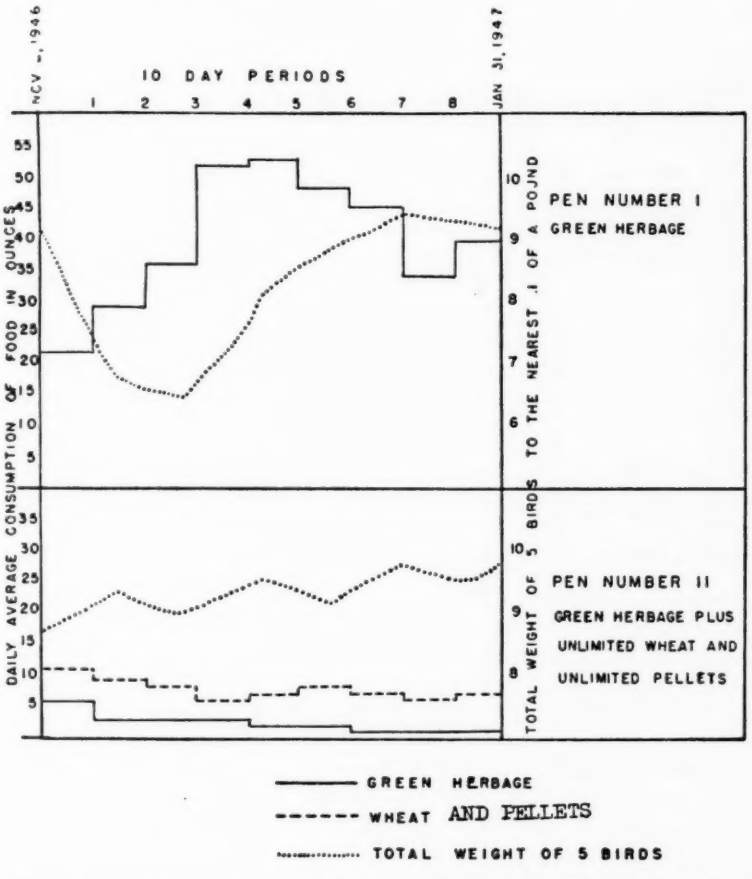
NOV 2, 1946
10 DAY PERIODS
1 2 3 4 5 6 7 8
JAN 31, 1947
DAILY AVERAGE CONSUMPTION OF FOOD IN OUNCES
TOTAL WEIGHT OF 5 BIRDS TO THE NEAREST .1 OF A POUND
PEN NUMBER I
GREEN HERBAGE
PEN NUMBER II
GREEN HERBAGE PLUS
UNLIMITED WHEAT AND
UNLIMITED PELLETS
GREEN HERBAGE
WHEAT AND PELLETS
TOTAL WEIGHT OF 5 BIRDS

FIG. 1. Daily average food consumption and total weight of the five birds (1 cock and 4 hens) per pen. Daily diets consisted of green herbage only, and green herbage plus varying amounts of wheat and Albers Pullet Grower pellets for each pen.

beginning of the experiment, November 2, 1947, every effort was made to accustom the birds to their new environment.

Each of the eleven pens used in this experiment held one cock and four hens. These floored pens measured five feet high, four feet wide, twenty feet long and were raised approximately two feet off the ground. A small house or coop was attached to one end of each pen.

Grit and water were available to the birds at all times. The food items and the amounts fed to the five birds in each pen are shown in Table 1. The amount of food consumed was recorded daily, and the birds were weighed every two weeks in order to determine the effect of the various diets.

One pen of birds was fed a commercial food known as Albers Pullet Grower, wheat, and green herbage in sufficient quantities to insure the availability of

Pen no.	Daily diet	Food consumption in ounces per bird per week
1	Unlimited green herbage*	59.9
5	Green herbage, 3 ounces wheat daily	42.2
8	Green herbage, 1.5 ounces wheat 1.5 ounces weed seeds daily	39.2
2	Green herbage, 3 ounces weed seeds daily	34.8
6	Green herbage, 6 ounces wheat daily	17.3
4	Green herbage, unlimited weed seeds	16.4
7	Green herbage, unlimited wheat	16.3
11	Control, green herbage, wheat, pellets	15.3
10	Green herbage, weed seeds, wheat	15.1
3	Green herbage, 6 ounces weed seeds daily	13.7
9	Green herbage, 3 ounces wheat, 3 ounces weed seeds daily	13.6

* Green herbage consisted of alfalfa during November and kale during December and January.

the three food items at all times. This pen was used as a control.

Nutritional analyses of the green herbage were made bi-weekly, but only once for the wheat and weed seeds which have proven to be quite stable in food value when in storage. The green herbage consisted of alfalfa during the first three 10 day periods (the time divisions used in the experiment) and kale during the remainder of the experiment. Nutritional analysis of the green herbage indicated that alfalfa was higher in crude protein content than kale.

Weed seeds were higher in both protein and fat content than wheat. The weed seeds used were present in the following percentages by weight: bird rape, *Brassica compestris* 37.28 per cent; lamb's-quarters, *Chenopodium album* 19.88 per cent; rye grass, *Lolium sp.* 13.37; sheep sorrel, *Rumex acetosella* 3.43; velvet grass, *Holcus sp.* 3.04; alsike clover, *Trifolium hybridum* 1.98; and other material such as cracked vetch etc., 21.02 per cent.

RESULTS

The first objective was to determine if pheasants could survive on green herbage alone. This phase of the experiment was fulfilled by feeding one pen of five pheasants alfalfa during November and kale during the remaining two months of December and January. Four birds that underwent this experiment died during the period when alfalfa was being fed, obviously due to the form in which the green herbage was fed. The fifth bird survived a full month of alfalfa feeding and two months of kale feeding, and finally ended the ordeal heavier than other hens that were fed a more balanced diet. Likewise other birds having a high percentage of green herbage in their diet in proportions never found as a daily diet afield were apparently normal at the conclusion of the study, covering about 90 days.

Since the analysis of kale and alfalfa shows the latter to be richer in crude protein, it seems reasonable to believe that it is capable of sustaining life if available to the birds under field conditions. It, therefore, seems probable that the other four birds would have survived had they been fed alfalfa tips and leaves instead of the entire plants or long shoots which caused "balling" in their gizzards in the absence of other foods to make a more digestible food mass.

Since kale is a common and desired

food wherever it is available, it is probable that pheasants would consume kale in preference to frosted alfalfa during the latter part of November when the diminishing supply of palatable alfalfa would prompt a change in green food. The substitution of kale for alfalfa, therefore, appears to be a natural change.

The high moisture content of the green herbage necessitated a higher daily consumption in order to obtain a sufficient amount of dry matter. When the fiber and moisture content are both very high, the intake of green herbage becomes greater which suggests the bird might have to face a condition where it could not consume a sufficient amount of green herbage to maintain itself. Only under such a condition

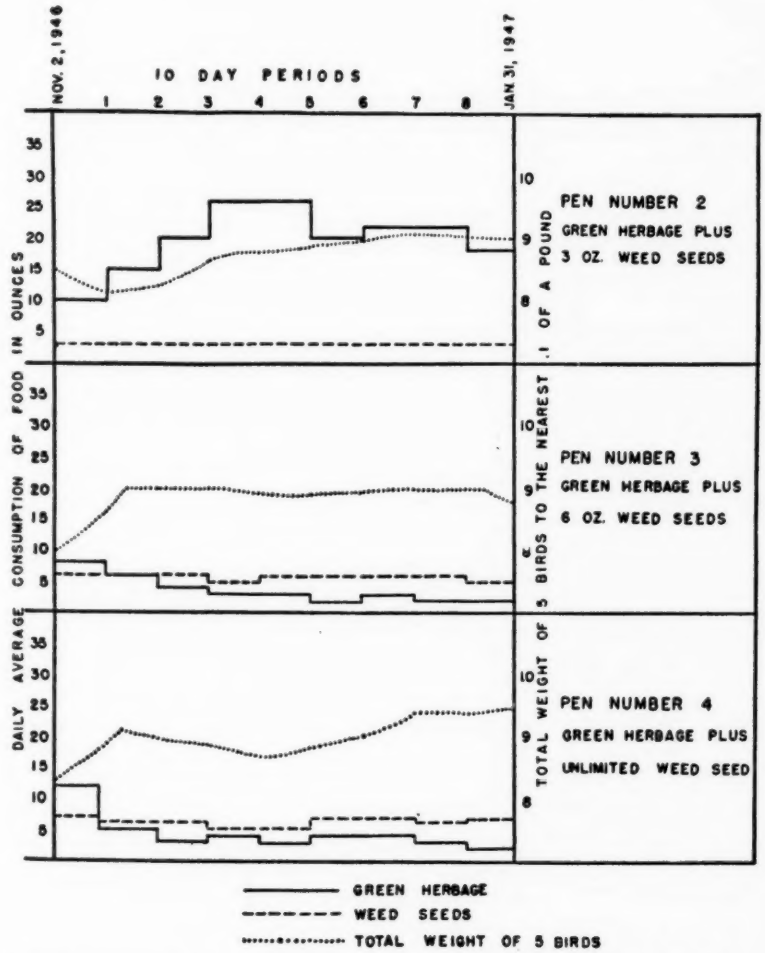
NOV. 2, 1946
10 DAY PERIODS
1 2 3 4 5 6 7 8
JAN 31, 1947
DAILY AVERAGE CONSUMPTION OF FOOD IN OUNCES
TOTAL WEIGHT OF 5 BIRDS TO THE NEAREST .1 OF A POUND
PEN NUMBER 2
GREEN HERBAGE PLUS
3 OZ. WEED SEEDS
PEN NUMBER 3
GREEN HERBAGE PLUS
6 OZ. WEED SEEDS
PEN NUMBER 4
GREEN HERBAGE PLUS
UNLIMITED WEED SEED
GREEN HERBAGE
WEED SEEDS
TOTAL WEIGHT OF 5 BIRDS

FIG. 2. Daily average food consumption and total weight of the five birds (1 cock and 4 hens) per pen. Daily diets consisted of green herbage plus varying amounts of weed seeds for each pen.

would it be impossible for pheasants to maintain themselves on green herbage.

Because of the climatic and habitat conditions found in the Willamette Valley, indications are that only on rare occasions would pheasants be confined to such a diet. Weed seeds and grain are usually easily found in the valley. Infrequently these might be unavailable in late winter or early spring but then the first small green sprouts are coming up, and consequently such a forced diet would be of short duration.

The second objective was to determine whether the addition of weed seeds are required for survival. The fulfillment of the first objective seems to indicate that weed seeds although not

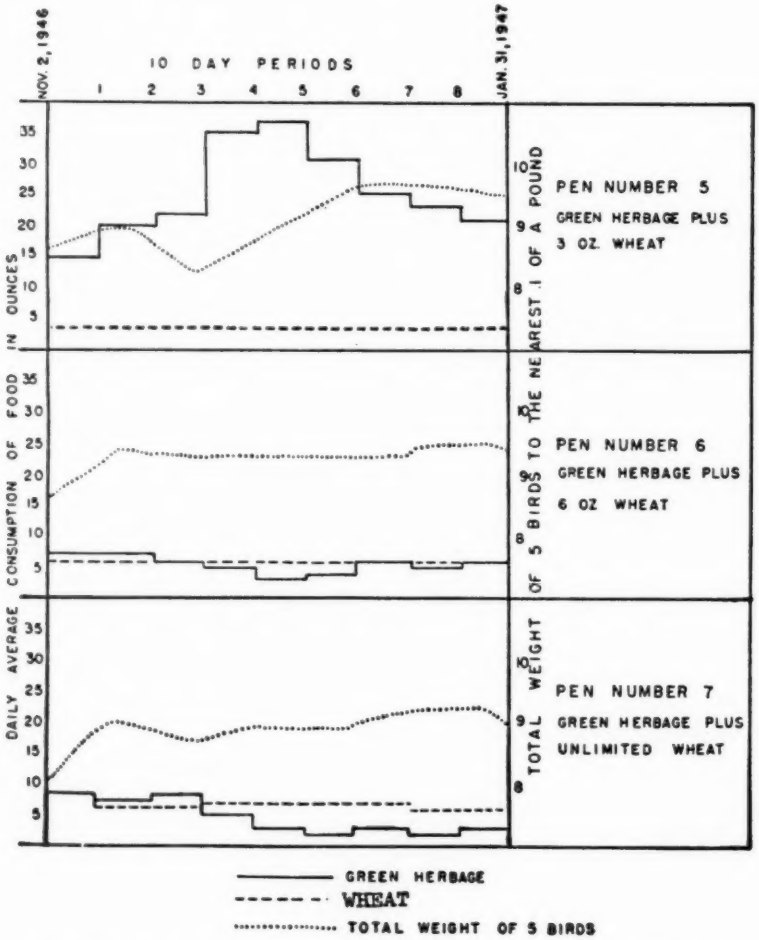

FIG. 3. Daily average food consumption and total weight of the five birds (1 cock and 4 hens) per pen. Daily diets consisted of green herbage plus varying amounts of wheat for each pen.

absolutely necessary when green herbage is of high quality, might be necessary when green herbage is nutritionally inadequate. This study indicated that weed seeds form an excellent buffer against malnutrition when only green herbage of poor quality is available. The birds having weed seeds in their diet were not ravenously hungry and did not gorge themselves with green food. During the period when alfalfa was being fed, there was no outstanding loss in weight which would seem to indicate that weed seeds when fed in sufficient quantity were nutritionally adequate to correct deficiencies. Also crop and gizzard binding did not appear due to the mixed food masses.

The third objective of this study was to determine whether the addition of

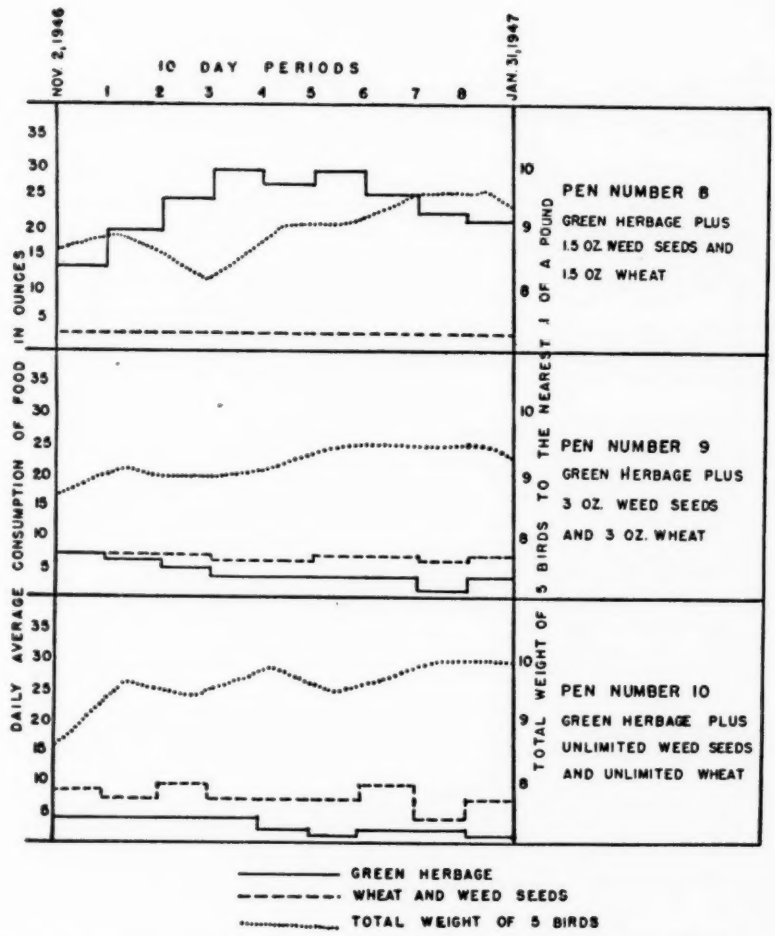
NOV 2, 1946
10 DAY PERIODS
1 2 3 4 5 6 7 8
JAN 31, 1947
DAILY AVERAGE CONSUMPTION OF FOOD IN OUNCES
TOTAL WEIGHT OF 5 BIRDS TO THE NEAREST ¼ OF A POUND
PEN NUMBER 8
GREEN HERBAGE PLUS
1.5 OZ. WEED SEEDS AND
1.5 OZ WHEAT
PEN NUMBER 9
GREEN HERBAGE PLUS
3 OZ. WEED SEEDS
AND 3 OZ. WHEAT
PEN NUMBER 10
GREEN HERBAGE PLUS
UNLIMITED WEED SEEDS
AND UNLIMITED WHEAT
GREEN HERBAGE
WHEAT AND WEED SEEDS
TOTAL WEIGHT OF 5 BIRDS

FIG. 4. Daily average food consumption and total weight of the five birds (1 cock and 4 hens) per pen. Daily diets consisted of green herbage plus varying amounts of weed seeds and wheat for each pen.

cereal grains such as wheat would be necessary for survival. Like the weed seeds the wheat proved to be a satisfactory buffer against malnutrition when fed in sufficient quantity. Although there was a loss in weight of the cock pheasant during the latter part of November when alfalfa was being fed, this could be attributed to individual variation since the weight of the hens remained the same.

When all three food items, green herbage, wheat, and weed seeds were fed to five birds, wheat seemed to be the preferred food. Results from other pens, however, indicated that weed seeds are a more suitable diet for maintenance than wheat when green herbage is scarce. Comparisons made are listed as follows:

1. Five birds receiving three ounces of weed seeds per day in their diet took *less* food than those receiving 1.5 ounces of wheat and 1.5 ounces of weed seeds daily in addition to the green herbage (Table 1).

2. Birds receiving three ounces of wheat in their diet took *more* food than those receiving 1.5 ounces of wheat and 1.5 ounces of weed seeds daily (Table 1).

3. Following the frosts in the latter part of November, when alfalfa was becoming unpalatable, the birds receiving three ounces of weed seeds in their diet *gained* weight while those that received three ounces of wheat lost weight (Figures 2 & 4).

4. Even though the birds receiving six ounces of weed seeds ate less food (5.6 ounces of weed seeds, 3.5 ounces of green herbage daily) they gained the same amount of weight as the birds that ate six ounces of wheat and 5.5 ounces of green herbage.

5. The birds that received six ounces of weed seeds ate the same amount of food as the birds receiving three ounces of wheat and three ounces of weed seeds, but the former gained more weight.

As mentioned, these comparisons would seem to signify that weed seeds are a better supplement to the diet than wheat when green herbage is scarce.

The fourth objective was to determine what proportions of the various food items were required for survival. Results of the experiment indicated that between three and six ounces of either weed seeds or wheat was the most desirable quantity of seeds for five birds to adequately supplement the green herbage eaten. As the amount of weed seeds or wheat became limited and green herbage was still abundant, the amount of total green food consumed by the pheasants increased three or four or even more times.

CONCLUSIONS

1. Pheasants were able to survive on green herbage alone for a period of three months, providing it was of proper quality and quantity. Protein in the green foods was shown to be quite high, ranging in the experiment from 27.22 per cent to 20.11 per cent.

2. Pheasants were able to survive and increase appreciably on green herbage and weed seeds only.

3. Pheasants were able to survive on green herbage and wheat only.

4. Between three and six ounces of either weed seeds or wheat for five pheasants per day were essential when the amount of green herbage was limited.

5. Wheat seemed to be preferred

over weed seeds and green herbage as a pheasant food.

6. The combination of weed seeds used in this experiment was appreciably of better quality for pheasant maintenance than was wheat.

7. As the amount of weed seeds or wheat became limited and green herbage was still abundant, the amount of total green food consumed by the pheasants increased three or four times, or even more, in weight.

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THALLIUM AND COMPOUND 1080 IMPREGNATED STATIONS IN COYOTE CONTROL

Weldon B. Robinson

Biologist, U. S. Fish and Wildlife Service, Denver, Colorado

The control of coyotes on many important stock ranges of the West is handicapped by the failure of control implements to operate effectively under adverse winter conditions. Efforts which are effective primarily during the warmer months of the year are capable of destroying large numbers of coyotes, but too often result in killing mostly the younger and inexperienced animals. Also, with such unequal seasonal pressure, a portion of the coyote population seldom greater than the annual increase is removed, leaving a breeding stock sufficient to replenish original numbers. It is axiomatic that effective control begins after a portion of the coyote population equivalent to the annual increase has been eliminated. Since efforts during the spring, summer, and fall are largely absorbed in removing the annual increase, winter operations immediately before whelping season assume great importance. Unfortunately, the winter control measures are generally less productive because freezing weather and snows limit travel by the operator and prevent his implements from functioning effectively.

The control picture is further darkened by the fact that many of the critical ranges are located at the higher altitudes where climatic conditions are more severe and coyote reduction by normal methods correspondingly difficult. Typical are the sheep industry's lambing grounds, which may be described generally as the foothill sections between the lower winter grazing districts and the higher forested summer ranges. Because of deep snows these areas cannot be grazed for several months during the winter, and are used primarily in the late spring and early fall.

Depredations suffered during lambing operations usually are more severe than those experienced at any other time. It is then that the coyote young are being reared, and there is an increased need for food by the adult coyotes. As a result the feeding of the

pups frequently may be accomplished at the expense of the lamb crop. To give the flocks the necessary protection, effective control must be practiced during the preceding winter months. The gap in the means available to combat coyotes under difficult winter conditions often nullifies the effects of previous efforts and leaves unprotected those very ranges for which protection is most needed.

To remedy this, experiments with poison-impregnated stations were started in 1937 by the Control Methods Research Laboratory of the U. S. Biological Survey.[1] During the earlier years thallium sulphate was the toxic agent employed, but with the discovery of 1080 (sodium fluoroacetate) in 1944 experiments were started with this newer poison. To appraise thoroughly the effects of these lethal stations on non-predatory creatures as well as on coyotes, studies have been conducted with increasing emphasis over a period of 10 years. This paper reports on these studies and shows the advantages and disadvantages of thallium and 1080-impregnated stations as a means of controlling coyotes.

[1] Later (1940) this unit became part of the Wildlife Research Laboratory of the U. S. Fish and Wildlife Service. Bernard E. Lowery initiated the studies during the winter of 1937–38; Noble E. Buell conducted studies the following two winters; the writer continued the work from 1940–41 through 1946–47, aided during the winters of 1944–45 and 1945–46 by Robert W. Sears. Numerous others of the Wildlife Research Laboratory, notably Donald A. Spencer, Justus C. Ward, H. J. Spencer, Maynard W. Cummings, and William H. Robison, contributed materially in various phases of the study. The assistance and cooperation of field men of the Division of Predator and Rodent Control also is gratefully acknowledged.

AREAS OF EXPERIMENTATION

The regions chosen for the experiments, mostly lambing grounds, were typical of areas in the western states where the operation of normal methods of control was difficult. In the winter of 1937–38 four thallium stations were exposed in an area embracing some 200 square miles in Lincoln County, Wyoming. During the following winter 1,800 square miles in this same county were treated with 16 stations, and in 1939–40, 71 were employed over a block of 5,000 square miles in Lincoln County and adjacent regions. During the winter of 1940–41 a new experimental area was set up on the lambing grounds north and east of Farson, Wyoming, in the adjoining sections of northern Sweetwater, eastern Sublette, and western Fremont counties. For three successive winters (1940–41 to 1942–43) 1,200, 1,400, and 1,600 square miles were treated, respectively, with 35, 34, and 42 thallium stations. During the latter season 12 also were used in a 250 square mile area in Natrona County, Wyoming.

In the winter of 1943–44 three experimental areas were set up in Colorado: some 600 square miles were treated with 21 thallium stations in Jackson County and 6 were employed in two blocks of approximately 100 and 200 square miles in Montrose County. Studies with thallium were continued in Colorado through the winter of 1944–45, when 99 stations were used in some 3,300 square miles in Jackson, Routt, and Moffat counties. During that winter 1080 was first used, with 10 stations carrying this poison being exposed in scattered areas in Routt, Moffat, and Jefferson counties in Colo-

rado. Studies then were intensified with this newer toxic agent. In the winter of 1945–46, 45 stations were employed in a block of about 1,600 square miles in Moffat County, Colorado, and 66 others were used experimentally, about one per township, in two areas in Owyhee County, Idaho and Elko County, Nevada. During the tenth year, twenty-five 1080 stations were employed over approximately 900 square miles in Las Animas County, Colorado.

STATIONS

In preparing a station (usually a carcass of a sheep or horse) thallium was placed directly in the meat through slits cut in the flesh. Compound 1080, being soluble in water, was applied in solution directly into the flesh by hypodermic syringe, or into the circulatory system by force pump. Late in the fall these "impregnated" carcasses were put out in natural coyote runways. In regions so large that drift of coyotes from surrounding localities did not threaten immediate re-population, stations could be placed so that on the average each would protect a relatively large area, ranging from more than 100 square miles down to approximately 30. When a "line" of stations was placed through a small region, the number employed would be relatively large since drift from all sides had to be considered. The stations were completely destroyed in the spring. Late exposure and early destruction was practiced to protect as much as possible migrant birds, hibernating mammals, and sheep-herding dogs.

EFFECT UPON DEPREDATIONS

To obtain information on the effect of these control measures upon depredations, representative sheepmen were interviewed. Such a method of appraisal has its limitations because most sheepmen do not maintain records of losses, and figures often must be supplied entirely from memory. Furthermore, an accurate determination of kills is difficult, especially when stock is grazed on the open ranges. Predator losses before station usage often were described with such general terms as "heavy," "considerable," or "appreciable," and after application of thallium or 1080 as "light," "negligible," or "none at all." Some representative sheepmen, however, were able to supply tangible estimates; these are summarized in Table 1.

The stockmen's reports show marked reductions in losses from predators following the use of the experimental stations—annual aggregate reductions ranging from a near 100 to 75 per cent. The consistency of the reports year after year in showing such reductions in the various regions is indicative of the effectiveness of this method of control. Even though the records may be only estimates, the stockmen do know whether their losses are heavy or light, and in this respect the figures portray the relative extent of depredations.

In addition to the actual losses suffered, the effect of a large predator population is felt by the stock industry in other less tangible but equally important ways. Close-herding is necessary when predators are abundant, and this practice is expensive in monetary outlays as well as in its effect upon livestock and range. More attention is necessary when sheep are bunched for protection from coyotes; the range is trampled and the stock suffer from inadequate forage. After application of

TABLE 1.—EFFECT OF EXPERIMENTAL CONTROL UPON DEPREDATIONS

Area, Year:	Poison used:	No. lambs docked by sheepmen interviewed:	Lamb loss during May and June prior to use stations:	Lamb loss during May and June after use of stations:	Per cent reduction in lamb loss:
Lincoln Co., Wyo., 1938–39	thallium	49,000	1,271	190	*88*
Same, 1939–40	thallium	38,100	1,228	62	*94*
Farson, Wyo., 1940–41	thallium	47,000	540	94	*83*
Same, 1941–42	thallium	62,800	980	177	*82*
Same, 1942–43	thallium	58,000	830	207	*75*
Jackson Co., Colo., 1943–44	thallium	9,700	152	6	*96*
Montrose Co., Colo., 1943–44	thallium	14,800	85	9	*84*
Jackson, Routt, Moffat, Co's., Colo., 1944–45	thallium	42,440	1,402	252	*82*
Routt Co., Colo., 1944–45	1080	3,300	68	1	*98*
Moffat Co., Colo., 1945–46	1080	29,730	1,093	161	*85*
Elko Co., Nev., 1945–46	1080	?	1,350	5	*99*
Totals			8,999	1,164	87 (Av.)

the thallium and 1080 stations, many sheepmen reported that they were able to practice more open herding with resultant benefits in the form of heavier lambs and less depleted range. Moreover, the effects upon depredations often were felt on adjoining summer ranges. Probably many coyotes drifted down during the winter from these forested and mountainous regions to the foothills, there to be destroyed by the lethal stations.

REDUCTION IN COYOTE POPULATIONS

Both thallium and 1080 are relatively slow in their toxic action, with the result that coyotes that succumb after feeding on the lethal stations are scattered over such wide areas that many are never found. However, sheepmen and others working in the experimental areas following the use of the stations have encountered large numbers of dead coyotes, and some of these counts, incomplete as they are, can be cited to show the effectiveness of the stations in reducing coyote populations.

In Lincoln County, Wyoming, during the spring of 1939, 136 dead coyotes were reported on the 1,800 square miles treated with 16 thallium stations during the preceding winter. These results can be compared with those obtained with the other methods of control over the same area and during the same period for six previous years. In expending an average of 15.6 man-months from November 1 to March 31 through the winters of 1932–33 to 1937–38, inclusive, the hunter force accounted for a maximum of 77, a minimum of 58, or an average of 65 predators per season. These animals were taken with steel traps, strychnine

stations, dogs, and rifles, and therefore the recorded catch more closely approached the actual kill than was so when the thallium stations were used. When it is considered that the count of 136 coyotes destroyed with the experimental stations represented only an undetermined part of the total kill, it can be appreciated why the sheepmen estimated a reduction of 88 per cent in depredations during the following lambing season.

In Moffat County, Colorado, during the winter of 1945–46, it was estimated that 299 to 394 coyotes were destroyed by forty-five 1080 stations employed over an area of approximately 1,600 square miles. These estimates were based upon the amount of feeding correlated with coyote activity observed at the stations during frequent visitations. Only 70 of these coyotes were reported found by sheepmen during ensuing lambing operations, but reports could not be obtained from many of the outfits. Nevertheless, the coyotes observed at some stations where careful observations were made so closely approached the numbers computed to have been killed at those sites, that the over-all estimate seemed well within reason. On this basis a further idea may be had of the value of the impregnated stations in controlling coyotes. Two competent Service hunters in working the area covered by the stations and adjoining regions collectively accounted for 546 coyotes and bobcats during the preceding year, including the period that the stations were in use. These men relied mainly upon coyote-getters, and with this procedure it is certain that scores of other coyotes were killed which could not be counted. The removal of roughly 300 to 400 more of these predators in the 1,600 square mile area, immediately before whelping season and in addition to the numbers taken by the hunters, spelled the difference between heavy and light lambing losses for the sheepmen.

In the higher regions, or where natural foods were scarce during the winter, the control of coyotes sometimes approached local extirpation. Where coyote foods were more available, generally at the lower altitudes the stations were less effective and follow-up work by the hunter force often was necessary to hold depredations at a minimum. In the latter areas the value of this method of control appeared to lie in its ability to reduce coyote numbers during the winter to a point where the hunter force was successfully able to cope with them during the ensuing lambing operations.

ECONOMY

Since impregnated stations remain effective throughout the winter without attention, the man-power requirements are considerably less than those needed in the use of other methods. The savings in the cost of control can be shown by a simple comparison of the efforts expended in the operation of the experimental stations and those previously used in the employment of other methods. The time required to put out and dispose of the 71 thallium stations used in a 5,000 square mile area in Lincoln County, Wyoming, and vicinity during the season of 1939–40 can be summarized as follows: one month preliminary work (arranging for bait, preparing equipment, and other planning operations), two months exposing sta-

tions and two months destroying stations by a man of supervisory capacity; two months by a hunter-assistant in putting out the stations. These combined efforts, exclusive of the time required in studying the merits of the method, totaled seven man-months. Previous experiences had shown that 25 man-months by the hunter force (five men from November through March) were expended in applying standard control measures within that same area, and many inaccessible sections were only partially or not worked at all.

There is little difference in the work required to operate thallium or 1080 stations, because the greater part of the labor—the actual exposing and destroying of the lethal meat—is a constant factor with both poisons. Of minor importance is the fact that 1080, because of its solubility in water, can be injected into the station meat with greater ease than the powdered and relatively insoluble thallium can be dusted into scored flesh. A major consideration, however, is the relative cost and availability of the two lethal agents. Because 1080 is 180 to 250 times as toxic to coyotes as is thallium, a much smaller amount of the former should be used per station. With 1080 costing $8.00 per pound and only 16 grams being required in the preparation of a 1,000 pound horse carcass (divided to make several stations), the material expense per horse carcass is only 28 cents. During recent years thallium has become increasingly scarce and costly, and at the present minimum price of $35.00 per pound, the corresponding cost of treating a 1,000 pound carcass with one-half pound of the poison is $17.50. Summarizing, therefore, with the two poisons being considered equally effective in controlling coyotes, 1080 has a decided advantage in its cost, availability, and ease of application.

CONTINUED EFFICIENCY

It is a generally accepted fact that a control method for either predators or rodents becomes progressively less effective with continued use. Formulas for the suppression of rodents have been highly effective during their initial employment, but with continued application the results deteriorate until a different lethal agent or bait must be substituted. The coyote is equally versatile in adapting itself to changing conditions. Over a period of years many of these predators have become so wary of the steel trap that it is extremely difficult to take some individuals with this implement. There are indications that coyotes are learning to evade a new device, the cyanide gun, which has been in use for only a relatively short period. During its early years of use the strychnine drop-bait station was hailed as the solution to the coyote problem, but eventually too many coyotes learned to detect the poison. Whether the thallium and 1080 stations will follow such trends has not been determined. There is evidence that some coyotes refuse to feed on these lethal stations, but the number apparently is not increasing. Because thallium is relatively tasteless and has no warning features, and 1080 is so toxic to members of the canine family as to almost preclude the possibility of sub-lethal feedings, it appears that a decline in the effectiveness of

these stations, if it occurs, will be gradual and less pronounced.

SELECTIVITY

The areas in which the experimental stations were employed were largely the sagebrush deserts, foothills, and plateaus. Predatory or carrion-eating creatures common to these regions, some of which may be expected to feed on the stations, were coyotes, bobcats an occasional domestic dog, badgers, skunks, weasels, eagles, hawks, owls, turkey vultures, crows, ravens, and magpies. During the season of 1944–45 in Colorado, a limited number of "vulnerable" stations were placed at higher elevations through the oak-brush regions and into the forested mountains. In such locations, chosen for a study of selectivity, they were well within the ranges of bears, foxes, mink, marten, and the carrion-eating long-crested and Canada jays.

To determine the frequency with which the various animals and birds fed, a most important consideration, visits were made to the stations whenever possible to record activity. Some were visited only when removed, while others were observed several times during the period of exposure. The feeding noted in making 1,038 visits to 329 stations is summarized by seasons in Table 2.[2] In presenting these data it should be stated that a record signifies merely that a creature or creatures of the kind indicated were known to have fed on the lethal meat; it does not imply the number feeding. It was relatively easy to determine whether coyotes or large birds or rodents had eaten the treated meat, but it was difficult or impossible to specify the numbers that had participated. Frequently a station was found to be heavily fed upon or entirely eaten with only signs of coyotes, or coyotes and magpies as the case may be, present. A large number of individuals, perhaps as many as 15 or 20 coyotes and an equal or larger number of magpies, may have participated, but the observation could be listed only as a "coyote" or a "magpie" feeding record. Field observations indicated that the confirmed carrion-feeders, particularly the coyote and the magpie, generally fed in groups or in large numbers, whereas the creatures which subsist on carrion to a lesser extent visited the stations singly or in small numbers.

Both thallium and 1080 are relatively slow in their toxic action, with the result that the creatures that succumb after feeding on the stations are scattered over such wide areas that complete counts can never be made. Stockmen, sheepherders, Service hunters, and others working in the experimental areas following the use of the stations have reported on the creatures found dead, presumably poisoned; the combined reports from these sources list the following: 888 coyotes, 3 bobcats, 37 dogs, 1 domestic cat, 2 badgers, 4 weasels, 8 eagles, 7 magpies, 4 hawks, and 2 ground squirrels. Some of these men were careful observers, but un-

[2] These visits were made by the writer and associates to stations in Wyoming and Colorado during the seasons 1940–41 to 1946–47, inclusive. Frequent inspections also were made by others at stations in Wyoming from 1937–38 to 1939–40, inclusive, and in Idaho and Nevada in the winter of 1945–46, but the records are not adaptable to this compilation.

TABLE 2.—FEEDING OBSERVED AT THALLIUM AND 1080 STATIONS

	Fall* (Oct., Nov., Dec.)	Winter (Jan., Feb., Mar.)	Spring (Apr., May, June)	Totals
Number visits	194	581	263	1,038
No feeding (or none since prev. visit)	46	262	50	358
Feeding by:				
coyotes	83	162	120	365
dogs	2	6	1	9
badgers	7	7	9	23
bears			6	6
foxes		1	2	3
mink or weasel		1		1
bobcats	1			1
canine-type**	16	105	80	201
eagles (doubtless golden)	4	22	4	30
hawks	1	3		4
crows or ravens	1	1		2
unid. large birds***	5	11	12	28
Magpies (or magpie-like feeding)****	85	109	46	240
jay, Canada	6		1	7
jay, long-crested		1		1
mice	6	24	6	36
ground squirrels			8	8
prairie dogs		1	1	2
kangaroo rat		1		1
unidentified	1	12	3	16

* The main period of placement was November and December, and of removal, March, April, and May. Some "vulnerable" stations used in the higher forested regions were put out in October, visited that month and later, and removed in early June.

** Nature of feeding generally indicated coyote, but definite evidence in form of tracks or feces lacking. This column also must contain some activity by other similar feeders, such as dogs, badgers, foxes, and bobcats. The ratio probably is somewhat in accordance with the identified feedings by these various mammals.

*** Either eagle, hawk, turkey vulture, crow, raven, or owl; probably mostly golden eagles.

**** Unquestionably most of this was by magpies, but other medium-sized carrion-eating birds, such as jays, occasionally may have been involved.

doubtedly the majority were interested primarily in predators, and therefore the compilation may be considered as emphasizing the coyote.

As a "check" against this larger list, those connected with this project, aided by searching crews, made extensive surveys of poisoned areas. In these endeavors 114 dead creatures were located, namely: 61 coyotes, 4 badgers, 1 mink, 28 magpies, 2 hawks, 3 eagles, 9 deer mice, and 6 ground squirrels. This list may be too small to be representative, but its composition is believed to reflect the actual kill more closely than the reports received from the rangemen.

The feeding observations and the records of creatures found dead show that a variety of animals and birds visited the carrion stations, but that the principal feeders were coyotes and magpies. Activity by crows and ravens also may be extensive in areas where these birds abound. Even though feeding by the other creatures was limited,

it would take on more serious aspects if it represented destruction of any appreciable portion of their respective populations. The effect might best be determined by a detailed census of animal and bird life before and after station exposure, but the magnitude of such a task, which would necessitate the counting of elusive and rarely observed animals and birds over large areas, was well beyond the time and man-power available. Furthermore, such counts might be limited in their value by normal fluctuations in numbers between fall and spring, seasonal migrations, and variations of animal and bird activity during the different periods. In lieu of a general census, an appraisal of the effect upon populations can be based upon the extent of station feeding correlated with the characteristics of the poisons, the habits of the various animals and birds, and such seasonal counts of their numbers as could be made.

CHARACTERISTICS OF THE POISONS AFFECTING SELECTIVITY

Compound 1080 and thallium stations are equally effective in the control of coyotes, but may affect the populations of other animals and birds differently. Thallium is considered poisonous in the same degree to all of the creatures that feed upon stations; 1080, on the other hand, is highly toxic to members of the canine family, but considerably less so to some of the other wild creatures. In preparing impregnated stations, enough poison must be placed in the meat to be lethal to coyotes which may eat only small amounts. With thallium small feedings also may be fatal to other animals and birds, but with 1080 those creatures having the greater tolerances may survive such or even much larger meals. Therefore, the records of activity at 1080 stations do not necessarily mean that all of the feeders were killed.

Extensive toxicological studies were conducted to determine the tolerances of the various creatures for 1080. It was found that the 50 per cent minimum lethal doses (LD 50) for a series of mammals and birds that might be endangered in station operations are: coyotes—0.1 mg./kg.; grey foxes—below 0.3 mg./kg.; bobcats—0.66 mg./kg.; badgers—1.0 to 1.5 mg./kg.; raccoons—above 2.0 mg./kg.; opossums—60.0 mg./kg.; magpies—0.7 to 1.33 mg./kg.; golden eagles—5.0 mg./kg.; four species of hawks—10.0 mg./kg.; great-horned owls—10.0 mg./kg.; and black and turkey vultures—above 50.0 mg./kg. These figures simply mean that badgers, for example, possess tolerances 10 to 15 times as great as that of coyotes, eagles are 50 times as resistant, and opossums have a margin of safety over 600 times that of coyotes. With stations prepared so that light feedings will be fatal to coyotes, it is evident that creatures possessing greater tolerances will have to eat correspondingly larger amounts of the meat to acquire lethal dosages.

To minimize the dangers to creatures having a greater resistance to 1080, a reasonably even distribution of poison throughout the station mass is necessary. This was best attained by injecting 1080 solution directly into the meat with a hypodermic syringe. It was found that the solution diffused some distance, and that by making numerous injections with a multiple-outlet needle a thorough, although not absolutely

even, distribution was obtained. During the season of 1946–47 in Colorado 25 stations, treated by hypodermic syringe with approximately 1.6 grams of 1080 per 100 pounds of meat, were used with excellent success in the control of coyotes. To determine the effect of stations prepared in this manner upon various creatures that may feed thereon, sections of the meat were given to animals and birds with the following results:

Seven coyotes died after being force-fed two ounces each (roughly three cubic inches) of the station meat, and it was indicated that some would have been killed by much smaller amounts.

Two badgers and one raccoon, after being fasted for 48 hours, voluntarily ate 11, 7, and 6 ounces, respectively. Only one badger died, but the other and the raccoon were left with nervous disorders which probably would have prevented their survival under natural conditions.

Three magpies were killed by voluntarily eating 19.4, 11.0, and 10.9 grams, respectively, of the station meat. It was indicated that 4.5 grams of meat should have carried lethal doses for average-sized magpies. Of seven others, fed this amount, four died, suggesting that an absolutely even poison distribution was not attained.

Four golden eagles were force-fed 10, 13, 16, and 22 ounces, respectively, of the station meat. The one receiving 16 ounces died, but the others recovered completely after being ill for a few days. It is unlikely that many eagles would eat such large amounts of station meat under field conditions. Ralph H. Imler[3] recorded the weights of the gullet contents of a series of bald eagles from Alaska, and 23 of the heaviest, described as "full," "very full," "crammed full," and "gorged," contained amounts varying from $3\frac{1}{2}$ to $22\frac{7}{8}$ ounces. The average content was 10.7 ounces, and only 5 had more than 16 ounces. Since these were meals under natural conditions, often representing gorging on fresh kills, it is unlikely that golden eagles of similar size would consistently eat greater amounts of station carrion which is frozen solid most of the time. Furthermore, repeated sub-lethal amounts of 1080 do not seriously injure eagles, but result in their acquiring a certain tolerance for the poison. One bird was given 32.5 mg./kg. of 1080 (more than 6 times the minimum lethal dose) over a 27 day period, including a final dose of 10 mg./kg. After exhibiting symptoms of poisoning, the eagle survived with no evident impairment.

Two ferruginous roughlegs and two marsh hawks were fasted for 48 hours and then were given all the clean natural food that they would accept. The next day an equal amount of station meat was force-fed to each bird—one of each species died, but the other two recovered completely. In a second series of tests, which probably are more indicative of conditions in the field, an American roughleg, a ferruginous roughleg, a prairie falcon, and a marsh hawk were accustomed to eating clean ground horse meat. The birds were held on the horse meat diet for more than two weeks, then were fasted for 48 hours and offered 1080 station meat in a free feeding test. Each ate less than an ounce, refused the balance, and survived without displaying any symptoms.

[3] Unpublished field notes in the files of the Wildlife Research Laboratory.

In an experiment conducted in Florida, there were no fatalities resulting from 104 black and 3 turkey vultures collectively consuming a 27 pound goat carcass carrying 5 times the concentration of 1080 employed in coyote control operations. Twenty-nine of the same black vultures then ate a 29 pound carcass treated at the same high toxic level, and only one of the birds died.

PROTECTION OF MAMMALS BY STATION DISPERSAL

With the exception of the opossum, the spread of the susceptibility of the mammalian carnivores to 1080 appears to be too narrow to permit the effective control of coyotes without killing many of the other mammals that also feed on such material. Such animals as the badger and the raccoon are 10 to 20 times as resistant as the coyote, but are capable of eating large lethal quantities of station meat. Smaller amounts may not be fatal, but probably will leave the animals with handicapping nervous disorders. Therefore, the 1080 station must be classed with its thallium counterpart as being dangerous to the common mammalian feeders.

In employing impregnated stations, there are precautions which can be taken to limit feeding by animals other than coyotes and thus protect their general populations. Of the common mammalian carnivores inhabiting the open sage brush ranges, the coyote maintains by far the widest range of travel. Therefore, stations can be placed at such scattered intervals in coyote runways that they can be found and fed upon by practically all coyotes in the general area, but by relatively few of the smaller and more sedentary mammals. In part of the experimental work, stations as far apart as 10 miles were used successfully, each controlling coyotes over an average of more than 100 square miles. Generally, however, placements were made at shorter intervals, mostly about 6 miles apart with each one effective over an average area of a township (36 square miles). With a thorough knowledge of the regions to be treated, and with a genuine determination to make a few stations do the work of many, an operator can effectively control coyotes and at the same time limit the feeding opportunites for the more sedentary mammals.

Placements should not be made in stream habitats where the smaller furbearers are found more frequently. Furthermore, by limiting the period of exposure as much as possible to the winter months when coyotes turn more to carrion because of food scarcities, hibernating mammals such as the badger and the skunk are given additional protection.

EFFECT ON PREDATORY BIRD POPULATIONS

The wide dispersal of stations and a careful choice of sites limit the feeding opportunities for the smaller carrion-eating mammals, but such protection does not extend to the predatory or carrion-eating birds which may travel even more extensively than the coyote. As shown earlier, 1080 stations are fairly selective with respect to these larger birds. Eagles, hawks, and owls possess tolerances 50 to 100 times that of coyotes, and are generally endangered only by the larger or starvation feedings. Under actual field condi-

tions relatively few will eat such large amounts, and most of those will survive the effects of the poisoning. Black and turkey vultures, and by inference the closely related and scarce California condors, are so resistant to 1080 that they are virtually beyond danger.

As far as is known, such discrimination does not exist when thallium is used; it is assumed that most, if not all, of the feeders are killed. Since there was considerable feeding by eagles on the stations and on the bodies of poisoned coyotes, concern was felt for their populations. Therefore, for three successive winters—season of 1944–45 when thallium was used, and the following two winters when 1080 was employed—daily counts were made of the large birds sighted while observers were visiting the stations. Because the 1944–45 census was more extensive, and was made in the presence of thallium stations which are considered more dangerous to the predatory birds, it is of greater value and will be discussed.

During that year 99 thallium stations were used over an area of approximately 3,300 square miles in northwestern Colorado. The count of live birds was started in December with the first full round of visits immediately after placement of the bulk of the stations, and was continued until the end of May when all but 2 of the stations had been removed. The birds sighted were rarely, if ever, more than 5 miles from a station site, and thus were the individuals most endangered. The data obtained are summarized by months in Table 3.

TABLE 3.—LARGE BIRDS OBSERVED IN THALLIUM AREA, COLORADO, 1944–45

	December	January	February	March	April	May
Hours spent observing	60	170	107	134	79	132
Miles traveled	618	1,274	760	759	622	901
Birds observed:						
Eagles*	35	93	63	80	24	19
Hawks**	5	19	10	35	78	138
Turkey vultures	9				7	3
Owls		1	1	1	1	2
Crows and ravens		12	1	15	35	20
Unidentified birds		4	5	1		2

* One bald eagle was observed in March and another in May; others were golden eagles.
** Largely Buteos with smaller numbers of falcons and Accipiters; American roughlegs predominated during the winter, but were outnumbered by red-tails and Swainson's in the spring.

During December 5.7 eagles were observed in an average distance of 100 miles. Counts for successive months in an equal distance were 7.3 in January, 8.3 in February, and 10.5, 3.7, and 2.1, respectively, in March, April, and May. The sharp reduction in eagle numbers during the early spring definitely was due to migrations out of these higher regions. Rather than successive decreases during the preceding months, as might be expected in view of feeding at stations, the populations appeared to show an increase. There was some evidence that the large March count was due in part to an influx of eagles before the general withdrawal,

and it may be that numbers during earlier months were bolstered by inward migrations. However, eagles repeatedly were observed in constant numbers at particular locations, suggesting that these actually were the same birds. If so, the larger monthly counts probably were due to conditions in the field which increased the incidence of eagles being sighted. Regardless of the cause, it is evident that eagles were maintaining sizable and satisfactory populations in the presence of the stations.

Hawks were generally scarce during the winter, but migrated into those regions in increasing numbers in the spring. This coincided with the period when rodents began emerging from hibernation. The counts showed hawk numbers in an average travel route of 100 miles to be .8 in December, 1.5 in January, 1.3 in February, and 4.6, 12.5, and 15.3, respectively, in March, April. and May. These records indicate that the greatest factor protecting the general hawk populations was their habit of migrating out of the foothill regions during the period of food scarcity; those remaining, however, maintained satisfactory numbers.

Other large birds were observed so infrequently that their population trends were not determined. Turkey vultures were absent during the winter; owls, being nocturnal, were rarely observed in the day time; and crows and ravens were counted irregularly, depending upon the sighting of their flocks.

DANGERS FROM SECONDARY POISONING

Because of the scattering of station victims, it is difficult to determine the variety of animals and birds that may feed upon the bodies of these poisoned creatures. On the basis of field experiences, however, the dangers of secondary poisoning would appear to be limited largely to eagles which feed extensively upon the carcasses of coyotes, and to magpies, crows, and ravens attracted by the eagle activity. Probably of less consequence would be feeding by scavenger birds or the mammalian carnivores on the bodies of magpies, or the occasional eating of coyotes by any of the other animals.

The best indication of the extent of secondary feeding was furnished when crews were used to search station sites for victims or their scattered remains. During 39 man-days of hunting, 18 coyotes, 20 magpies, 2 golden eagles, and 2 hawks were located. Of these, 9 of the coyotes had been eaten in typical eagle fashion, and at least 8 of the magpies either were completely eaten, with only scattered feathers as evidence, or the remains were so dispersed as to suggest scavenger action.

Thallium and 1080 may react differently in secondary poisonings. It must be recognized that thallium is voided continuously by the living victim, and much of it may have been eliminated by the time death occurs. Small amounts also may be deposited in the muscles, but since the poison is not particularly dangerous in minute amounts and there is no marked differential in susceptibility between various creatures, the secondary feeders would have to eat prodigious quantities of the tissue of the primary victim to be affected even in a slight way. The chief if not the only danger, therefore, would lie in those cases where the internal

organs were eaten, and the possibility of secondary poisoning would become quite real if the primary victim had eaten large quantities of the station meat and died immediately.

Since eagles and the accompanying magpies, crows, and ravens invariably consume the viscera of a poisoned coyote first, and scavenger action by these birds is much greater than that of the other creatures, the extreme effects of secondary poisoning should be reflected in eagle numbers. Undoubtedly some were killed through such feedings but, as shown earlier by the eagle counts, these birds maintained sizable and satisfactory numbers not only in the presence of thallium stations but while consuming literally scores of poisoned coyotes. It is inconceivable that such populations could have persisted if many of the eagles feeding upon coyotes had been fatally poisoned.

It seems less likely that deaths would result from the larger birds or mammals eating the bodies of magpies, because the smaller birds are generally incapable of eating enough meat to be lethal to the larger creatures. To obtain dangerous doses of the poison, the larger animals or birds probably would have to eat the bodies of several magpies, with the poison being "bulked" by the magpies' weights.

Emesis is generally the first response of animals and birds to 1080 poisoning, with the result that the excess lethal material in the stomachs or gullets is deposited at various points around the station. Since the alimentary tract is thus emptied, its toxicity is so lessened that it probably presents reduced hazards to secondary feeders. Rather, the danger would appear to lie in direct poisoning from creatures eating the regurgitated material. The vomitus of a coyote generally is deposited at several points, and may range from relatively undigested station meat to mucus. Because of its being scattered and partially digested, any creature eating this disgorged material would ingest only a portion of the poison taken by the original feeder. Some canines, magpies, or cats probably would be killed by such feedings, but the dangers would appear to be less to the other creatures because of their greater tolerances for 1080.

In the field trials it was feared that the scattered vomitus from coyotes might result in the killing of dogs even after removal of the stations. However, following the use of 146 stations over a three year period, during which hundreds of sheep-herding dogs were employed in 1080 areas in the spring, only one report was received of the possible poisoning of a dog in this manner. It can be concluded, therefore, that the vomitus disintegrates rapidly and becomes relatively harmless in warm weather.

Summarizing, it is indicated that the secondary poisoning of creatures eating the internal organs of coyotes killed by thallium stations, or the direct poisoning of those feeding upon the vomitus disgorged by 1080 victims, is possible under some circumstances, but does not appear to be extensive. Because a certain amount of thallium is voided by each victim, and the remaining quantities are "bulked" by the inert body, is highly unlikely that lethal doses could ever be passed to a third feeder. Likewise, 1080 vomitus would become so scattered and unpalatable with each

successive ingestion that a third poisoning would seem impossible.

STATIONS IN FORESTED REGIONS

During the season of 1943–44 in Jackson County, Colorado, two stations inadvertently put out too high in the mountains were reached by bears. To learn more regarding the dangers of such placements to this game animal as well as to mink, marten, and red fox, thallium stations purposely were exposed during the season of 1944–45 in certain "vulnerable" locations in the mountainous and forested regions. Fifteen placements were made in the higher areas normally considered to be "out of bounds," and 13 others were used in the intermediate regions between the forests and the foothills. Although 24 of these were fed upon by coyotes and the remaining 4 by unidentified canines (probably coyotes), 3 of the 15 higher stations were known to have been fed on by bears, 2 by foxes, and 1 probably by a mink. In addition, fox feeding was recorded at 1 of the 13 stations in the intermediate zone, and a wandering bear reached another in the higher foothills. The frequency of bear and fox feeding and the possible dangers to mink and marten, demonstrate that lethal stations cannot safely be employed in such forested habitats.

OTHER OBJECTIONABLE FEATURES

Poisoning as a method of control is undeniably objectionable, but may, according to viewpoint, be considered justified in those cases where necessary reductions in coyote numbers cannot be accomplished by other means.

Control by the use of either thallium or 1080 leaves much to be desired as far as their killing actions are concerned. Laboratory studies show that large doses of thallium may prove fatal to victims within 24 hours, but that most animals eating this toxic agent in smaller but lethal amounts succumb within 2 to 5 days. The minimum lethal dose may require even a longer period to kill. With sub-lethal doses, recovery may require several weeks during which there is partial disability, emaciated condition, and loss of hair. Compound 1080 is faster in its action, but the spasm period of its victims, particularly the canines, seems unduly violent. With coyotes, symptoms may be delayed from one to several hours, depending on the dose taken. After emesis the animals generally pass through a period of excitement—cowering, yelping, or violently running as though in fear—before falling in convulsions. The period of affliction may vary from 15 or 20 minutes with the larger doses to an hour or much longer with successively smaller amounts. The severe spasms associated with 1080, and the time required for thallium to kill, especially when minimum dosages are ingested, are outstanding objections to the use of these two particular poisons.

The impregnated stations are not suitable as a means of taking pelts, because only a small portion of the coyotes killed can be found before the fur spoils. Their use, therefore, results in the loss of considerable fur.

There is no effective antidote for either poison after the toxic symptoms have set in, and each is dangerous to the handler because of different characteristics. Although thallium has a lower toxicity, it is cumulative in its action

and may be absorbed through the skin. On the other hand 1080 is more toxic but is not cumulative, and, because of its solubility, may more readily contaminate water supplies. Operators should exercise extreme caution in handling the poisons to protect not only themselves but others.

CONCLUSIONS

There is a pressing need for an additional method of coyote control to be used during the winter in acute predation areas. Coyote populations, relatively unaffected by other methods, were greatly reduced following application of thallium or 1080 impregnated stations, and estimates of predation likewise showed similar trends. The lethal stations were especially effective in reducing troublesome coyote populations in regions that are largely inaccessible in the winter. The two poisons are equally effective in controlling coyotes, but 1080 is preferred because it is cheaper, more readily available, and somewhat more selective and easier to apply.

It is entirely possible by careful handling of such a dangerous tool as lethal carrion to suppress coyotes and in doing so affect other populations to a lesser degree. In desolate foothills and sagebrush plains, where the winter carrion-eating creatures are limited primarily to coyotes, badgers, skunks, weasels, magpies, eagles, and hawks with fewer numbers of bobcats, domestic dogs, owls, turkey vultures, ravens, and crows, impregnated stations, with proper handling, can be used effectively to control coyotes without seriously disrupting the populations of many of the other animals and birds. With the exception of the magpie, the collective toll of other creatures exacted in lethal station operations is not large, and the drain on any one species relatively light. The occasional poisoning of any carrion-eater is inevitable, but by placing stations to take advantage of the coyote's habits, populations of desirable creatures are largely protected by their own individual characteristics.

Impregnated stations should be widely spaced along coyote runways to take advantage of that predator's ranging habits and to limit the number of "danger zones" for all other carrion-eaters. Habitats along streams frequented by the smaller fur-bearers should be avoided. The stations should be exposed at the latest date practicable in the fall and removed as early as possible in the spring to afford protection to the hibernating and migrating species. When employing 1080, the poison should be carefully regulated and distributed in the station carcass to limit its toxicity to predatory birds which have a high, protective tolerance. By exercising meticulously such precautions, coyotes can be generally reduced with magpies locally affected and other creatures killed in relatively small numbers. Any deviation from such a schedule, either in procedure, timing, choice of location, or in density of station placements, is destined to give results at variance with those experienced in this study.

There is admittedly a danger from secondary poisonings, particularly to creatures that feed upon the alimentary tract of thallium-killed coyotes or eat the vomitus disgorged by 1080 victims, but this does not appear to be so exten-

sive as to appreciably alter the selectivity of this method of control.

Use of impregnated stations in forested regions is inadvisable in view of the increased likelihood of killing bears, foxes, and other furbearers frequenting such habitats.

The employment of 1080 or thallium impregnated stations, and the extent of such use, is a matter for serious consideration. On the credit side of the ledger is the remarkable ability of this method of control to reduce, sometimes to the point of local extirpation, the most troublesome coyote populations. This can be accomplished at a fraction of the cost of ineffectively operating other methods. From an economic standpoint the resultant savings of livestock, which otherwise would fall prey to the coyote, weigh heavily in favor of the employment of this method. On the other hand, these poisons are severe in their killing actions; they may be dangerous in the hands of inexperienced operators; there is a loss of pelts that cannot be recovered; and desirable or neutral creatures inevitably will be poisoned. With careful handling of stations, however, these losses may be kept at a low level.

Let it be emphasized that the impregnated thallium or 1080 station is not a method for general or promiscuous use. As set forth in the policy statement of the Fish and Wildlife Service, "Compound 1080 and thallium may be used in the Fish and Wildlife Service program of coyote control only by employees who are specifically 'authorized . . . . " and "These individuals shall be held accountable for compliance with Service policies." The stations " . . . shall be employed judiciously in conjunction with other approved control methods . . . " and " . . . the average placement on any given range used as the control unit shall not exceed one per township." They " . . . shall be established as late in the season as practicable, and shall be removed as early in the spring as possible. . . . Authority for early or late exposure of stations, beyond the period stated above, shall not be given under any circumstances."

"Stations shall never be used in areas inhabited by fur animals, or in any area where beneficial wildlife will be endangered thereby. For this reason, stations shall not be placed in or close to timbered areas or near streams and other waters, except where such environments are positively known not to be inhabited by valuable fur animals. . . . Very careful scrutiny shall be given to environments potentially valuable for fur animals, regardless of whether such species are actually present."

ARTIFICIAL DENS FOR RACCOONS

Frederick W. Stuewer
Michigan Department of Conservation, Lansing, Michigan

Other workers (Hawkins and Bellrose, 1941, and Hesselschwerdt, 1942) have described artificial nesting and denning sites developed for and accepted by several game species, notably wood ducks and fox squirrels. The purpose of this paper is to give a brief account of studies concerning artificial den boxes for raccoons (*Procyon lotor*) with a description of a box found to be acceptable to them.

A knowledge of the denning habits of raccoons makes it evident that the preservation of existing dens and provision of some kind for a continued supply of dens is strictly essential to maintaining favorable raccoon populations. In different parts of the country this species is known to utilize several kinds of denning sites. Giles (1940) found them to be denning in the cracks and fissures of limestone outcrops in eastern Iowa. In Missouri, according to Bennitt and Nagel (1937), they occasionally use ground burrows, but tree dens are by far the most important type of site. This is quite true for raccoons in Michigan. Here also they live in ground burrows or tiles, where they are forced to it, but tree cavities are preferred and are used wherever available. Raccoons seem as much at home in a tree as on the ground, and it is in a tree that they seek not only refuge from pursuers but a home for a family as well.

It should be kept in mind that raccoons are among the few of our native mammals that never build their own homes. Squirrels often occupy tree dens but they also build leaf nests; woodchucks sometimes live in tree cavities near the ground, but more often dig their own burrows. Many of our mammals can provide their own homes when necessary. The raccoon, though adaptable in so many ways, has not learned the art of home construction. In view of these facts and of the ever-decreasing number of the larger trees capable of furnishing dens, it seems important for the future maintenance of raccoon numbers that other means of furnishing this animal with home sites be given consideration.

The writer was leader of the first Pittman-Robertson research project in Michigan, Raccoon Management Investigations. That study was made at the Swan Creek Wildlife Experiment Station in the southwestern part of the state from February 1, 1939 to July 1, 1941. It was during those investigations, after considerable study had been made of natural tree dens, that an artificial den box was designed and erected to determine primarily if it would be acceptable to raccoons.

Before the study began, there were already 50 wood duck nest boxes along a bayou on the Experiment Station. These were periodically examined in 1939, 1940 and 1941 to determine the use made of them by ducks and to ascertain whether raccoons might be using them also, even though many natural tree hollows existed. Signs indicated that only a few of those boxes had been visited by raccoons, and a two-

thirds grown individual was found occupying one in August, 1939. The scant use thus indicated was considered evidence that such boxes were not especially attractive to this fur-bearer. They were designed for wood ducks and as shown by later studies, their measurements did not conform to those of natural raccoon dens. The round entrances were only 4½ inches in diameter, near minimum for an average-sized raccoon, and the entrances were on the front of the boxes which might further handicap a raccoon trying to enter. In the only instance of occupancy, the box was so placed in the tree that a branch extended alongside the doorway.

By 1940, the principal investigations had progressed to the point where considerable data had been accumulated about natural tree dens. Such information was interpreted with a view to designing a new artificial den approximating the average natural den in as many respects as possible. Although there was wide variation among the occupied dens, the average measurements were about 14 by 12 inches for the inside diameter and 38 inches for the depth from entrance to bottom.

These data were taken from 34 tree dens found occupied by raccoons. Den boxes were therefore constructed according to the following specifications. Made of rough one inch lumber, they measured 14 inches square by 36 inches in height (Plate 8*A*). The entrances, measuring 4 by 6 inches, were located next to the roof, and to the rear on one side, so that they would be easily accessible to raccoons trying to enter. The back of the box was extended above and below the den proper to facilitate nailing to a tree. Tops were hinged to allow easy inspection. A wire comb was fastened along one side of the entrance to catch hairs of any entering animals. In each box a small quantity of sawdust was placed to keep the bottom dry and provide a bed similar to that of a natural tree cavity (Plate 8*B*). Fifteen boxes of this design were erected in early July, 1940. They were placed at distances varying from 25 to 40 feet from the ground, in several species of tree, and with various exposures of the entrances. The habitat where they were located is a creek-bottom, which transects an upland, sandy plain supporting mainly second growth white and black oak. Natural dens seemed to be rather few in the area. This territory is especially favorable for raccoons as far as food is concerned, with the creek furnishing a permanent supply of water and many aquatic forms upon which raccoons feed. In years of good acorn production the oaks furnish an abundant fall food supply upon which they gorge and fatten themselves for winter.

During the seven years that the boxes have been up, seven examinations have been made, but they were not ideally distributed. Of the first four, three were made in 1940 during the first four months after the boxes had been placed, and the next was made the first spring, May, 1941. Another was made in June, 1942. From then until 1946, during the war years, lack of personnel made it necessary to curtail many phases of study at the Station, and these den boxes were not examined until June of 1946, when the writer was back once again at the Station and had the opportunity to make further inspections. The last check was made in June, 1947. In compiling the data on

den use, the 1942 examination has not been included, since no mention was made in the notes for that year as to whether hair or other evidence of use by raccoons was found. Such evidence was recorded for unoccupied boxes at all other inspections.

Table 1 presents certain characteristics of the tree sites in which the boxes were situated, height and entrance exposures of the boxes, and information concerning the extent to which the den boxes were used.

TABLE 1.—DATA FOR 15 ARTIFICIAL DEN BOXES ERECTED IN JULY, 1940, AND USE MADE OF THEM BY RACCOONS.

Tree			Den		Results of den box examinations					
					1940			1941	1946	1947
Species	Diam. breast height	Distance to water	Height	Exposure of entrance	Aug.	Oct.	Nov.	May	June	June
White ash	15 in.	50 ft.	35 ft.	West					S*	S
American elm	24	100	30	Northwest	S				S	S
Basswood	14	75	30	West					S	S
Soft maple	15	40	35	West					S	**
Basswood	13	50	35	North	S			S	S	
Basswood	14	35	33	Southwest					S	S
American elm	22	100	30	South	S			S		***
American elm	13	50	35	North	S					S
Rock elm	19	10	35	South	S	S			S	L
Basswood	18	100	25	Southeast					S	S
White oak	22	15	40	Southeast	S	S			S	O
American elm	25	15	35	East	S				S	S
American elm	24	100	30	West	S				L	
American elm	15	200	30	Southwest	S				O	O
Black oak	16	50	35	Northwest	S	S			L	

* S—Signs such as hair or scats.
O—Occupied by adult raccoons.
L—Occupied by litters of raccoons.
** Part of bottom fallen out.
*** Box missing. Believed taken for honey as bees were in it in 1946.

Seven species of trees were included among those in which boxes were placed. Raccoons at one time or another entered boxes in all of them. These include American elm, rock elm, white ash, soft maple, basswood, white oak, and black oak. It is the writer's belief that species of tree means little to a raccoon if there is a den available, except that the smooth, hard bark of American beech might hamper the animals enough that they would pass up a good den in that species. This is mentioned here because on one occasion released raccoons were noted to have great difficulty in trying to climb beeches whereas they were adept at going up nearby oaks. The tree diameters at breast height ranged from 13 to 24 inches. Trees of such size are most apt to contain natural dens and it seems advisable that artificial dens be placed in specimens of about that size.

The distance from den tree to water varied from 10 to 200 feet. Raccoon occupants were found in dens at both the maximum and minimum distances

from water. Raccoons are known to use natural dens in nearby areas as much as one-quarter mile away from water.

All of the boxes were placed well within range of heights above ground determined for occupied natural dens, and within this small group of artificial dens the height differences seemed unimportant. About 35 or 40 feet is considered the proper height for a den to be placed.

Den entrance directional exposure appeared to matter little to raccoons also. Occupied boxes included those with entrances facing the south, west, southeast, and northwest. This was in agreement with what had been learned previously about natural dens; that is, that the suitability of a hollow in other respects seemed more important than the direction in which the entrance faced.

Table 1 also shows the results of six inspections of these den boxes during a period of seven years. One immediately notices the evidence of considerable raccoon activity in the dens one month after they were erected, August, 1940, and then again six and seven years afterward. The intervening examinations, later in 1940 and in 1941, showed little evidence that the boxes had been used at those times. The good showing of activity in August, 1940 may be explained by the fact that 10 pen-reared raccoons were released in the vicinity at the time that the boxes were erected. It is believed that these animals did a great deal of exploratory traveling in the vicinity immediately after release. Then, as seems characteristic of stocked animals, they probably moved out to other areas, and the boxes were without visitors later in 1940.

Little evidence of use was found in 1941 also. Evidently neither native raccoons nor any of the released animals, some of which may have remained, were using the boxes to any extent one year after their being placed. As previously stated, one inspection for which there are incomplete notes, was made in 1942. No occupants were found, but signs of use were not recorded. Whether or not raccoons used the boxes during the intervening years is not known, but in 1946, 13 or 87 per cent showed signs of being used or were occupied. Two contained litters of raccoons and a third harbored a lone adult. In 1947, one box was found uninhabitable with a part of the bottom fallen out, and another was missing altogether. The latter contained a swarm of honey bees in 1946 and undoubtedly was removed in late fall by persons out to secure the honey. Of the remaining 13, 77 per cent showed evidence of use, three of them being occupied, one by a litter and two by single adults. One of the adults was a pregnant female, which appeared to be near parturition.

From the evidence just now discussed, it would seem that raccoons may not be willing to use artificial dens until several years after they have been up. Further study might show this not always to be the case. Affecting most of our wildlife investigations there are often uncontrollable factors at work to influence the results secured. In this case there is the fact that Michigan's raccoon population increased tremendously from 1940 to 1947. The hunter and trapper take, according to their report cards, was 87,007 raccoons in 1946 compared to 31,512 in 1940. Competition for dens could be a definite

factor in determining the amount of use less desirable sites would receive and perhaps how much use artificial den boxes would receive. The relatively low population of 1940, compared to that of 1946, may have allowed all raccoons to find natural dens in this particular area with no need for them to use the artificial boxes until later when the population showed considerable increase. In areas where natural dens are extremely scarce, with even a low population of raccoons competition for dens could be severe and artificial sites might be used almost immediately. In many localities in Michigan today natural dens are few and far between and den boxes might be used much sooner than the ones observed in this study.

Of the 15 artificial dens erected, only one was uninhabitable after a period of seven years. This is important when the cost is being considered. The original cost of the boxes used in this study was low, amounting to about $1.25 each. The used lumber was valued at only $10.00 per M. Bd. ft. and labor at $ .45 per hour. Current prices of both materials and labor would undoubtedly more than double the present cost of such a box.

In selecting desirable areas in which to provide artificial raccoon den boxes, still another fact concerning raccoon denning habits might well be kept in mind. Some evidence is available (Stuewer, 1943) that raccoons may congregate more or less in rather restricted areas, at least in winter. Within about 40 acres of one study area, where denning conditions were especially favorable, eight occupied dens were found within a period of a few days in February, 1940. Undoubtedly some others existed which were not located. Apparently this small portion of the larger tract was attractive enough to cause the animals to concentrate in the area where, it seemed, they were willing to tolerate close neighbors. In view of this, and since raccoons seem to indicate no tendency to defend territories, it may be advisable that whereas only one artificial den per 10 or 15 acres might be placed advantageously in extensively wooded areas, as many as one per four or five acres might be placed in woodlots of about 40-acre size, and still more per unit area in a five or 10-acre woodlot. Such smaller tracts conceivably might serve somewhat as communal denning areas for raccoons carrying out most of their activities in surrounding open country. This could be true especially of much of Michigan's best raccoon range—the better farming areas of southern Michigan.

SUMMARY

Three facts serve as important reasons why the acceptance of artificial den boxes by raccoons should be important to wildlife managers. They are, first, that in Michigan and many other states raccoons have been found to prefer tree hollows to ground denning sites. Secondly, the raccoon is one of our animals that seems entirely incapable of constructing its own home. Thirdly, the number of natural denning sites in the form of tree cavities continues to decrease annually.

During a two and one-half year study of raccoon habits and management, average measurements were obtained for 34 natural tree dens found occupied by raccoons. Using such measurements,

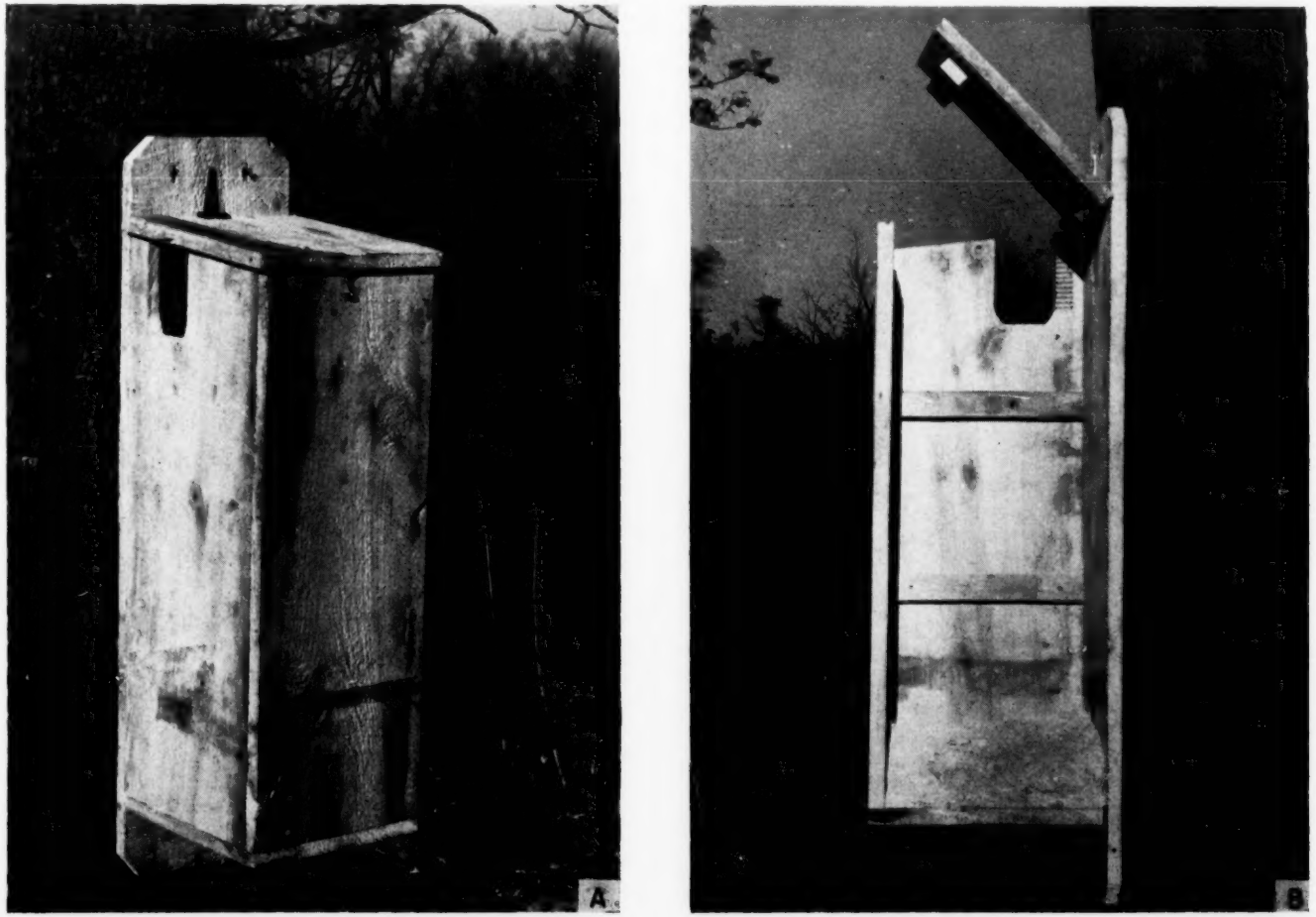

PLATE 8.—*A*. The artificial den is constructed of rough lumber with the entrance conveniently placed for raccoons to enter. *B*. Cleats should be provided to aid animals in getting in and out. Several inches of sawdust furnish a bed and help keep the box dry.

15 artificial den boxes were designed and erected in good habitat in July, 1940. Periodic examinations were made over a period of seven years.

Species of tree, diameter of tree, and directional exposure of the box entrance seemed to be unimportant in influencing raccoon use of the dens.

It appeared that native raccoons did not use the boxes for the first two years at least. By the sixth and seventh years there was considerable evidence of raccoon activity in them. In 1946, 87 per cent showed evidence of being used; two boxes were occupied by litters, and one by a lone adult. In 1947, 77 per cent contained evidence of raccoon use, three being occupied: one by a litter, one by a pregnant female, and one by a single adult male.

There is some evidence that small wooded areas with a great abundance of good dens may serve as community denning areas for animals which are active over extensive contiguous territory. This is a clue to the possible value of numerous dens in fairly small woodlots.

Present available knowledge indicates that artificial dens are best located within one-quarter mile of a permanent water supply.

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AN AIR CENSUS OF DALL SHEEP IN MOUNT McKINLEY NATIONAL PARK

Lowell Sumner

Biologist, National Park Service, San Francisco

On June 2, 1947, an air census was made of the principal Dall sheep (*Ovis dalli*) range in Mount McKinley National Park. This was to supplement ground observations that are being carried on continuously by Dr. Adolph Murie, Biologist, National Park Service, as a major wildlife conservation project. The purpose of the present report is to show the practicality in Alaska of a properly timed sheep census by air and, in particular, the close corroboration that this particular census gives to the detailed population counts made by Dr. Murie from the ground.

Territory Covered

Fortunately, the census was made at exactly the right season. The white coats of the sheep made them easy to see (Plate 9*B*) on their concentrated wintering grounds, from which the snow had largely melted. The more scattered summer range was still covered with much snow. It had not yet been occupied by the animals and therefore could be omitted from the flight schedule.

From the standpoint of a sheep, Mount McKinley National Park is divisible into three[1] main areas:

1. The lofty, glacier-clad crest of the Alaska Range on the south side of the park, culminating in Mount McKinley at 20,300 feet. This enormous, but remote and forbidding region, comprising about a third of the park, is a biological wasteland during most of the year. For a brief period after the middle of June, the heavy blanket of snow retreats sufficiently to permit revival of scant arctic vegetation along the basal slopes. The sheep then use the area as a summer range until the early winter drives them out again. At one time, when the sheep population was greater, these basal slopes were used more extensively, and afforded a limited winter range. Even today, the northern tips of the basal slopes in the Toklat area are used in winter. However, at the time of the present census it proved to be necessary to cover only the northern fringes of this vast territory.

2. The lower, more rounded and hospitable hills, sometimes called the Outside Range, on the north side of the park, terminating about opposite Mount McKinley near Kantishna. Elevations do not exceed 5,850 feet, and snowfall is comparatively light. Here the sheep spend the long winter months, particularly on the south face of the range where the spring sunshine brings the most rapid and early retreat of the snowbanks (Plate 9*A*). This region, if one includes only the favorable habitat, comprises much less than a quarter of the entire park area. The great majority of the sheep was concentrated here at the time of the census, making observation easy.

3. The rolling tundra, treeless and devoid of rocky shelter, that separates

[1] A fourth, smaller area, north of Mount McKinley and west of Kantishna, is low tundra of minor importance for sheep.

the lofty Alaska Range from the low hills of the Outside Range. For the sheep this is a no-man's land that must be crossed twice a year as they migrate between their winter and their summer feeding grounds. On this open ground they must briefly run the gauntlet of the wolves, and from the various false starts and the nervous haste with which they make the crossing, it is obvious that they sense their danger.

At the time of the census only two or three bands appeared to have made the summer crossing. However, less than a week later, Dr. Murie witnessed the commencement of a mass migration, and subsequently we traced another of these crossings from the hurried flight of footprints across the park road and a nearby stream bank. Both crossings appeared to have been accomplished safely, as no doubt were the vast majority of the migrations this year, for wolves were undeniably scarce.

METHOD

The airplane was an 85 horsepower Cessna, Model 120, which seats the pilot and one passenger side by side. It has a normal cruising speed of 100 miles an hour, but can be slowed down to 80 miles an hour for observation work. The tank holds 25 gallons of gasoline, and fuel consumption is four gallons per hour at slow speeds; thus the plane has a five-hour cruising range with approximately one hour's fuel reserve. The fuel cost averaged 2 cents per mile at Alaskan and Canadian gasoline prices, but is about 25 per cent less in the States. Service ceiling is supposed to be 15,500 feet when fully loaded with two persons and 80 pounds of baggage; however, I have used this plane for photographic work as high as 17,000 feet several times when lightly loaded.

The census operation was simplified by the fact that Dr. Murie's intensive field studies made known in advance the general location of the bands. Before taking off, a flight route was worked out that would take us parallel to all cliffs and slopes on both sides of the Outside Range, with side trips into each of the bisecting canyons that have been cut through these mountains by various glacial rivers coming down from the main Alaska Range.

By flying at an average altitude of about 5,000 feet, it was possible to maneuver the plane freely within the canyon walls at a height where they were at a maximum distance apart. At this altitude most of the sheep were 1,000 to 1,500 feet below the plane but their white coats were readily seen.

The actual flight followed the predetermined route closely except that occasionally, where large numbers of animals were grouped closely together, it was necessary to circle once or twice to get a complete count. Canyons too wide to census by a flight over the middle were covered by a zigzag course from one wall to the other.

Ranger Harold Booth, as the observer, counted each band of sheep and marked its location on a map of the park while the writer maneuvered the plane and took the photographs.

RESULTS

Four hundred eighteen sheep were counted in the four hours of flying. From a close area-by-area check with Dr. Murie's ground count of well-known bands made before and subsequent to this flight, it develops that 180 animals

were missed from the air. This brings the total to 598 sheep proven to inhabit the park.

Undoubtedly the above-mentioned error was due to lack of practice in conducting a census in this type of terrain, and could have been reduced or eliminated on a second flight. Some difficulty was experienced by the observer in counting the many bands of sheep and simultaneously locating their positions on the map, which he had to continually rotate in a direction opposite to the motion of the plane in order to maintain its correct position relative to the ground.

CONCLUSIONS

In evaluating this method of conducting a census the most outstanding conclusion appears to be that, if properly timed, the results can be surprisingly accurate even on the first attempt. The fact that an air count can be made in about one-eighth of the time required for a ground count makes the airplane a valuable tool, particularly for quick checking of changing conditions. However, this usefulness in no way diminishes the basic importance of careful, long-term ground studies.

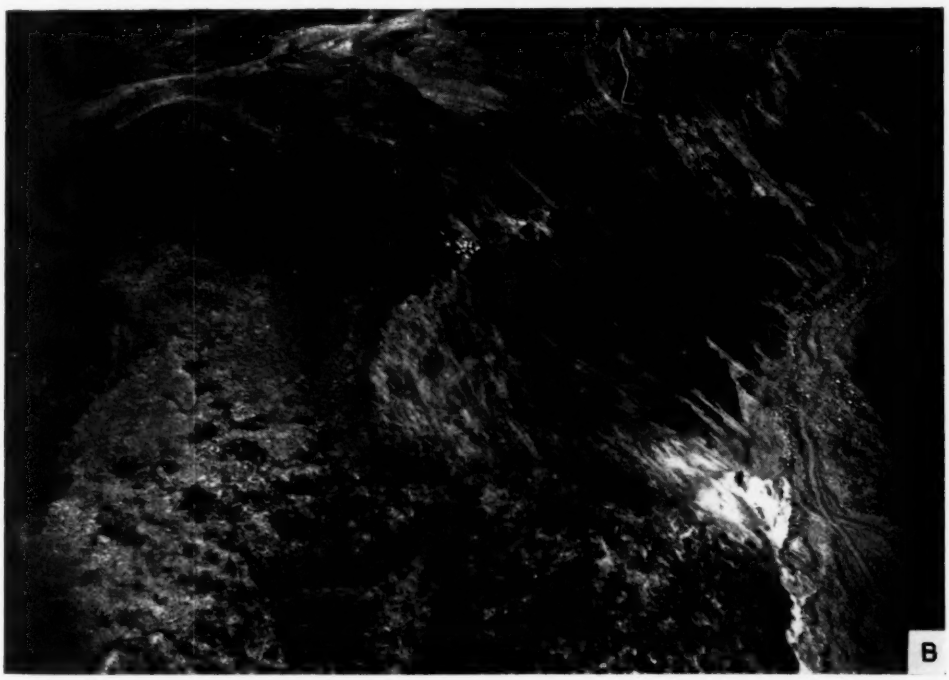
To count the lambs separately from the adults would have required additional circling, involving about twice the time and mileage of the present census. However, if necessary it could be done another time. Ground studies made with Dr. Murie showed a lamb crop of about 50 per cent in relation to ewes. In view of this good lamp crop, plus the fact that the sheep count indicated an increase from 500 in 1946 to 598 in 1947, the outlook is favorable for continued gains in the population.

EXPLANATION OF PLATE 9

A. The lower, more rounded and hospitable range on the north side of the park, where snow disappears relatively early, comprises the Dall sheep winter and spring range. Here in less than a fourth of the park, the great majority of the sheep was concentrated.

B. Air photo of a band of 14 sheep on edge of cliff (upper center) at Polychrome Pass. The wide-angle camera makes such objects appear *smaller* than as seen by the unaided eye.

A


B

SPECIAL ARTICLE

THE USE OF ROTENONE IN FISHERIES RESEARCH[1]

Louis A. Krumholz

Introduction

The native inhabitants of many widely separated tropical and subtropical countries have used extracts from rotenone-containing plants as an aid in catching fish since time out of mind. The aqueous extract, obtained by crushing the leaves, stems, or roots of the appropriate plant, upon being poured into the selected body of water, so stupefied the fish that they were readily caught. In Australia, Oceania, and Southern Asia the poison is generally known as *tuba* and is referred to as *tuba merah, tuba puteh, ackar tuba,* etc., depending primarily on the species of plant used. Such plants in that region usually belong to the genus *Derris,* the most common of which are *D. elliptica* and *D. uliginosa.* In tropical South America, on the other hand, the stupefacient is known under the various names of *cubé, timbó, barbasco, haiari, nicou, conapi, pacai,* and others depending on the plant and the locality. Such plants are of several genera amongwhich *Lonchocarpus* and *Trephosia* (*Cracca*) have been prominently mentioned by various authors. In North America, particularly in the southeastern United States and near the Gulf of Mexico, *Tephrosia virginiana,* known as devil's shoestring, goat's rue, turkey pea, etc., was well known throughout its range to the Indians who used it as a fish poison.

One of the earliest accounts of fish poisoning was that of John Nieuhoff (Pinkerton, 1813), who spent eight years in Brazil prior to 1649. He related that the native Brazilians baited the water with leaves, bark, fruit, or roots of certain plants that made the fish swim to the surface of the water as though dead so that they were readily caught in small nets. Juan and de Ulloa (1758) described a method of fishing used by the Indians on the Guayaquil River in 1736 as follows:

> " . . . Sometimes, especially in places where the creeks form a kind of lake, they make use of a certain herb called Barbasco, which they chew, mix with some bait, and scatter about on the water. The juice of this herb is so strong that a fish on eating a very little of it becomes inebriated so as to float on the surface of the water, that the Indians have no other trouble to take them up . . . ."

An early account of "tuba fishing" in the East Indies is that of Rumph (1747) in which he discussed several plants used by the natives in stupefying fish. Among those plants, one, described under the name of *Tuba radicum* or "ackar tuba" (*Derris elliptica*), was used solely for fishing purposes. The roots and nodules were crushed, sometimes with small shrimps or prawns and mixed with human dung, and then placed in the waters to be treated. Another account is by Marsden (1784) in which he stated that the natives of Sumatra steeped the roots of a certain creeping plant called *toobo,* of strong narcotic qualities, in the water where the fish were observed. The effect of the drug caused the fish to become so in-

[1] Contribution No. 372 from the Department of Zoology, Indiana University.

toxicated that they appeared dead and floated to the surface where they could be picked up by hand. Haddon (1901) and Hose and McDougall (1912) described the ceremonies that accompanied tuba fishing among some tribes in Borneo.

The earliest reliable account of the North American Indians using extracts of rotenone-containing plants in stupefying fish was that of Adair (1775). Later, Speck (1907) described the use of *Tephrosia* as a fish poison among the Yuchi Indians. Swanton (1946: 342–343) gave the following account of fish poisoning by the Creek Indians:

> "... Each man was instructed to provide himself with a quantity of the roots of a plant popularly known as 'devil's shoestring,' which grows on sandy ridges in the woods. He also carried a post, about 4 inches in diameter and 4 feet long, and a wooden mallet. Arrived at the appointed place, the men ranged themselves in a row across the head of the pond and drove their posts into the stream bed until the tops of the posts were almost on a level with the water. Then they pounded up the devil's shoestring with their mallets, allowing the pieces to fall down into the water. If there were any fishes in the pool, they would begin to throw themselves out of the water before the pounding was finished, but no one tried to kill any before that time. Afterward, the men took bows and arrows, spears, and other weapons, and descending into the pool they often killed great numbers of fish, which by now would be floating around on the surface ...."

That same author gave another account of such fishing in which the fishermen were accompanied by a medicine man who prepared medicine that, upon being drunk by the fishermen, prevented the fish from going down into their holes and thus escaping capture.

Other writers have shown that the extracts of rotenone-containing plants have been used as fish poisons by natives of the Malay States, the Philippine Islands, India, Ceylon, Fiji, the Loyalty Islands, Formosa, Australia, Panama, Peru, Mexico, the Guianas, Colombia, Mauritius, tropical Africa, and others.

In many regions the more desirable plants were actually cultivated by the natives and when needed for poisoning fish they merely cut pieces off the roots or branches without destroying the plants. At the present time such plants are under commercial cultivation in various parts of the world. According to Foote (1929) *Derris* root was shipped commercially from Sumatra to the United States for the first time in 1928. Since then its use as an animal and agricultural insecticide has been widespread. Little (1931), having found that aqueous suspensions of the powdered roots of *Tephrosia virginiana*, native to the United States, compared favorably in toxicity with *Derris*, pyrethrum and nicotine sulfate as an insecticide, suggested that the commercial possibilities of the plant be investigated. Although individual plants varied considerably in their rotenone content depending on the locality, soil, etc., he found later (Little, 1935) that the plants probably could be grown successfully on a commercial scale. Clark (1933) showed that the ether extract of the roots of *T. virginiana* possessed essentially the same toxicity as pure rotenone when tested as a fish poison. The United States Department of Agriculture, in cooperation with the Texas Agricultural Experiment Station (Sievers, et al., 1938), found that *T. virginiana*, and another species. *T. latidens* were the only species native to the United States that were of interest as a commercial source of rotenone. In the meantime, cubé and timbó are in com-

mercial production in South America.

Rotenone has been found only in members of the family Leguminosae, and, to date, in only 6 genera of that family, namely, *Derris* (*Deguelia*), *Lonchocarpus*, *Mundulea*, *Spatholobus*, *Tephrosia* (*Cracca*), and *Millettia* (Sievers, *et al.* 1938). It is an alkaloid with the empirical formula $C_{23}H_{22}O_6$ and was first isolated by Nagai (1902) from the roots of *Derris chinensis*. Since then rotenone has been isolated from plants of the genus *Lonchocarpus* and has been shown to be identical with that from *Derris* (Clark, 1929). Other closely related compounds, tephrosin, deguelin, and toxicarol have been isolated from those and various other plants (Clark, 1930, 1931). A digest of the literature on *Derris*, containing 456 references was prepared by Roark (1932).

Although it has been known for centuries that extracts of rotenone-containing plants are toxic to fishes, the use of rotenone by ichthyologists and fish management people has come into its own only recently. So far as the writer can ascertain, Eigenmann (1912) was first to take advantage of the native custom in making collections of fishes in British Guiana. On his later trips to other parts of South America, special effort was made to obtain *cubé*, *barbasco* or *timbó* to facilitate collecting (Eigenmann and Allen, 1942). Hubbs (personal communication) used powdered derris root with 5 per cent rotenone content in collecting from virtually unseinable waters in Guatemala in 1934 and elsewhere since then. The writer found powdered derris root quite effective in collecting small fishes in salt and brackish water in Florida in 1940.

Rotenone was first used in fisheries management at the suggestion of Dr. Carl L. Hubbs, then Director of Michigan's Institute for Fisheries Research. That first attempt at eliminating undesirable fish populations was made on two small ponds on the estate of Mr. W. O. Briggs near Birmingham, Michigan, that were overrun with goldfish (*Carassius auratus*) and carp (*Cyprinus carpio*). The ponds were treated with an aqueous suspension of powdered derris root (5 per cent rotenone) on July 17–23, 1934, under the supervision of Mr. Milton B. Trautman. Being chary of the potentialities of the drug, dilutions of between 0.04 and 0.1 p.p.m. of rotenone, based on estimates of the volume of water in each pond, were used. Although many thousands of fish were killed during the treatment, later seining showed a moderate survival in both ponds. In September 1934, a 4.3-acre lake in Otsego County, Michigan was treated in an effort to eliminate a population of stunted perch (Eschmeyer, 1937).

The Fisheries Research Board of Canada was first to follow the pioneer work done by Michigan on the use of derris in fish management. M'Gonigle and Smith (1938) used rotenone to clean out 25 miles of stream and a 6-acre lake above the newly built Cobequid Hatchery in Nova Scotia during August 1936. This was the first instance of the use of derris in the elimination of undesirable fish from a stream. Michigan continued to develop the method on other lakes in the Lower Peninsula of the state in 1936 and 1937 (Eschmeyer 1938a, 1938b, 1939; Eschmeyer and Clark, 1939). Shetter and Leonard (1943) used rotenone to study the trout population of a limited section of a stream in Michigan in 1940.

Following that preliminary work in

Michigan and Nova Scotia, powdered derris root has been used in fisheries management by many research organizations in the United States and Canada. In 1938, the National Park Service (Barrows, 1939), New Hampshire (Hoover and Morrill, 1938; Warfel, 1939), and Illinois (Thompson and Bennett 1939a, 1939b; Bennett, 1943) began to use rotenone in renovating lakes and streams. Since then more than 30 lakes have been poisoned in each of the states of Michigan and Illinois and 20 have been so treated in New Hampshire (Siegler and Pillsbury, 1946). It is probable that a considerable number of such studies have been made which have not been published. Still other accounts have been mimeographed and have not been widely distributed. Some are only briefly mentioned in annual reports. The following states and provinces are known by the writer to have used rotenone in renovating lakes or streams: Alabama, Arizona, California, Florida, Illinois, Indiana, Iowa, Kansas, Maine Manitoba, Michigan, Minnesota Missouri, Montana, New Brunswick, New Hampshire, New York, New Mexico, Nova Scotia, Ohio, Oklahoma, Ontario, Oregon, Utah, Virginia, Washington, Wisconsin, and Wyoming. Of course there may be others, of which the writer is unaware, that are not included in the list.

FIELD PROCEDURES

It is generally agreed that a concentration of 0.5 p.p.m. of rotenone by weight is lethal to most kinds of fish. That figure was suggested by Leonard (1939) after having exposed fish of 8 different species to several concentrations of the drug for various periods of time in aquaria. It has been worked out that 1.36 pounds of derris root (5 per cent rotenone) is sufficient to give a concentration of 0.5 p.p.m. of rotenone in one acre-foot of water. Thus, the amount of powdered derris needed for any body of water may be readily ascertained by multiplying the volume in acre-feet by 1.36.

Even though a concentration of 0.5 p.p.m. of rotenone has been shown to be lethal to certain kinds of fish under aquarium conditions (Leonard, 1939), experience in the field by the writer, and probably by others as well, indicates that a uniform concentration in all parts of the body of water under treatment is difficult to obtain.

In making the aqueous suspension of powdered derris it is easier to make a rather thick batter first and then dilute it to the desired consistency for application. Inasmuch as rotenone is insoluble in water, care should be taken to crush all of the lumps so as to give better dispersal.

Rotenone, in the form of powdered derris root, timbo or cube, may be applied by any of several methods. Application by pouring a dilute aqueous suspension in the wake of a moving outboard motor was first described by Eschmeyer (1937). That method of application to the surface water was supplemented by setting off charges of dynamite in the deeper parts of the lake to assure adequate distribution of the poison. Another method used in early experiments in Michigan was that of spraying the aqueous suspension over the water surface by means of portable pumps such as those used in fire fighting (Leonard, 1939). A third method was that used by M'Gonigle and Smith (1938) in which the powdered root was placed in openmeshed

burlap sacks and towed behind a boat. Here the sacks required periodic kneading in order to drive the insoluble powder through the meshes. In each of these methods it was the practice to disperse the drug in a criss-cross pattern over the entire lake surface. In a lake that is so treated there is little chance for the fish to escape contact with the poison. As the original cloud of batter sinks, it gradually disperses in all directions. In the shallower parts of the lake, where boats could not readily be taken, the suspension was usually sprayed or scattered with a small dipper.

There have been many modifications of the above-mentioned methods. In New Hampshire, paper bags filled with a thin batter of derris powder were tossed out from shore. Upon impact with the water the bags burst and the poison was released. In California, following detailed preparations for the elimination of lake chubs (*Siphateles obesus*) from Gull Lake, and using methods similar to those employed by workers elsewhere, Vestal (1942) used pistol shots to start the piscicidal affair.

That rotenone can be used to eradicate one kind of fish from a lake while sparing other kinds was first reported by Davis (1940). Under the direction of Stillman Wright, large numbers of Utah chubs were killed in Fish Lake, Utah, without harming the more desirable trout. Further studies on the selective poisoning of fish were made by Greenbank (1941) in Michigan. Greenbank found that, inasmuch as comparatively little derris root penetrated to the deeper, cold water of two trout lakes, the populations of yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*), and largemouth black bass (*Micropterus salmoides*) were almost completely eliminated with little harm to the brook trout (*Salvelinus fontinalis*). However, the suckers (*Catostomus c. commersonnii*), which inhabited the same waters as the trout, were also spared. Wales (1942) reported that rotenone was very effective in carp control work in Lake Almanor, California. Between 10,000 and 12,000 adult carp were killed during 1940 by applying an aqueous suspension of derris root to coves in which the fish were spawning.

In a personal communication, Dr. Gerald P. Cooper informed the writer that in 1939 the Maine Department of Inland Fisheries and Game undertook to eradicate the population of white perch (*Morone americana*) from Sabbathday Lake in an effort to make the lake suitable for the reestablishment of brook trout. The lake, approximately 300 acres in extent, was treated during the fall overturn with water temperatures at approximately 44°F. Six tons of timbo powder were dispersed through burlap bags towed behind outboard motors. Following the treatment it was conservatively estimated that over 200,000 white perch along with 300,000 other fishes had been killed. No complete counts were attempted. Information from Commissioner G. J. Stobie states that seining and gill netting have not yielded any white perch in the 8 years since the poisoning. The removal of the white perch and the reintroduction of brook trout have been combined to yield highly successful angling for the latter species.

Experience has shown that bullheads (*Ameiurus* spp.) and possibly other kinds of fish, are more resistant to the action of the drug than are centrarchids or trout. One instance illustrating such resistance is that of a pond of 1.4 acres

in Knox County, Indiana. That pond was treated with sufficient derris root to give a concentration of between 1.0 and 1.5 p.p.m. of rotenone. An aqueous suspension of the powder was dispersed in a checkerboard pattern in the wake of an outboard motor. The edges of the pond were carefully sprayed with the suspension so that any fish which sought refuge in the shallower water could not escape the drug. A total of 260 pounds of bullheads per acre were taken from the pond following the treatment. Most of those fish were in a stunted condition. However, some of the bullheads apparently survived the action of the drug because several broods of young were observed the following spring. The reasons for such a survival of bullheads are not obvious. It may be that the physical characteristics of the water (e.g. temperature, hardness, etc.) were such that the effects of rotenone were dissipated quickly enough so that the fish were able to survive the action of the drug for that short time. Then too, it may be that the dispersal of the rotenone was not uniform throughout the pond, although every attempt was made to make it so.

Because it has been realized that derris does not readily penetrate the deeper parts of a lake when applied to the surface, various methods have been employed to introduce the poison into such places. Weighted gunny sacks of the powder have been towed through deep water in New Hampshire (Siegler and Pillsbury, 1946), California (Vestal, 1942), and elsewhere with reasonable success. Krumholz (1941) reported satisfactory results by using an inverted funnel attached to the end of a piece of garden hose. Sash weights fixed to the distal end of the hose made it possible to penetrate to depths of 30 feet in a Michigan lake. Here the funnel caused sufficient suction to pull the derris suspension from a tank in a boat propelled by an outboard motor. In reclaiming East Fish Lake, Michigan, for brook trout, the writer and Dr. David S. Shetter found that a centrifugal pump dispersed the suspended derris adequately to all depths. A pipe fitted into the end of the spray hose made it possible to force the batter well into the hypolimnion. Siegler and Pillsbury (1946) reported that in New Hampshire all other methods of dispersal have been forsaken in favor of the spraying technique.

The writer has participated in the poisoning of well over 30 bodies of water and feels that a combination of spreading an aqueous suspension of derris root in the wake of an outboard motor over the deeper parts of the lake together with the use of pressure sprays in the less accessible littoral area is adequate for most lakes of a lesser depth than 20 feet. Certainly this combination is as rapid and inexpensive as any other. If, however, the lake is considerably deeper, some method should be used to get the poison into the deeper reaches provided they are habitable by the fish.

The problem of cleaning out spring holes and feeder streams in bog lakes gives trouble in some cases. Sinking a coarse-meshed bag of moistened derris powder into such places has been tried with good results in Michigan. The use of dynamite by inexperienced handlers in such areas may lead to disastrous results. A centrifugal pump equipped with a pipe so that the derris could be forced down into the holes may solve the problem if the terrain is suited to the

transportation of such equipment. Again, in treating bog lakes, where there are overhanging bog mats, a centrifugal pump could readily force the poison well under the mat. In any event, it is usually imperative that all undesirable fish in the lake are killed and no one method can be used under all circumstances. The method or combination of methods that works best is the one to use.

The action of rotenone on fishes depends to a certain extent on the temperature and hardness of the water being treated. If the water is relatively hard and the temperature high the effects are usually manifest in less than half an hour. As the temperature and hardness become reduced the speed of the action diminishes. Brown and Ball (1943) found that the water temperature at Third Sister Lake in Michigan during the first week in May was far below the optimum desired for best results. Because of those unfavorable temperatures they stated that the kill of fish was incomplete. A repoisoning of the lake during the latter part of August was successful.

Water temperature at the surface should be 75°F. or more for best results. However, Cooper successfully treated Sabbathday Lake in Maine in November 1939 when the water temperature was approximately 44°F.

The rotenone used in poisoning a lake may retain its potency for various periods of time depending on the physical properties of the lake water involved. In hard, slightly alkaline lakes the poison becomes dissipated in the rather short period of a week or ten days, whereas in extremely soft, "battery water" lakes the drug will retain its effectiveness for a month or more. Thompson and Bennett (1939a) began to restock Fork Lake, Illinois, within four days of the application of the derris powder. M'Gonigle and Smith (1938) noted that the waters of McCormick Lake, Nova Scotia, were toxic to fish for about a month.

A simple test to ascertain whether or not the waters of a lake are toxic to fish is to suspend a wire cage of fish in the lake. If the fish in the cage are not dead at the end of 24 hours, the chances are that the lake is ready for restocking. In making this test, however, it should be kept in mind that the cages are not to be placed in areas where there might be insufficient dissolved oxygen to maintain fish life.

Inasmuch as the numbers of fish killed during the poisoning of a lake are large, methods of disposal must be taken into consideration. In some instances samples may be preserved for study in the laboratory but such preserved material usually constitutes a very small fraction of the total population. Burial of the dead fish near the lake is generally the best procedure. From one to several pits, their size and number depending on the number of fish, dug near the site should suffice for the interment. Thus the stench that accompanies the decay of fish flesh is largely eliminated. In areas where raccoons and other fish-eating animals are present, care should be taken to bury the fish deep enough so that they are not readily accessible to such animals.

Vestal (1942) employed a bulldozer for two days to excavate a pit for the disposal of lake chubs killed in Gull Lake, California. Unless there are many tons of fish to be buried such expense seems unwarranted. In general, one or two men with shovels can bury all the

fish taken from a lake. Siegler and Pillsbury (1946) suggested the lowering of the lake level prior to the poisoning and then, after the fish are dead and the counts are made, refilling the lake to its former level so that the odors accompanying the putrefaction would not be so offensive. In addition, those workers cited the possible value of the decaying fish as fertilizer. It is the opinion of the writer that, if the lake level can be lowered with any facility, the thing to do is to drain the lake and dispense with the poisoning altogether. Most lakes have an inherent fertility that has maintained a fish population for many years prior to the treatment and should be able to support as great a population subsequently. The value of the fertilizer in such situations is questionable. The benefit, if any, to be derived from the decaying fish would at best be temporary and the unsightliness of the dead fish, even though covered by several feet of water, is certainly an item to be considered in a resort area. In agricultural regions the fish may be fed to hogs or may be placed on the land as fertilizer following the precedent set by the natives of this country.

Most lakes that are considered worth reclaiming by rotenone are less than 100 acres in extent. In fact, very few with a greater area than 30 acres have been treated. In rare instances larger lakes, such as Back Lake, Pittsburgh, New Hampshire, having an area of 358 acres (Warfel 1939) and Sabbathday Lake, Maine, about 300 acres in extent (Cooper, personal communication) have been treated on an experimental basis. The treatment and subsequent management of such lakes is much more difficult than those of lesser proportions. If the first attempt at eliminating the fish is unsuccessful, a "repeat performance" is almost out of the question because of the expenses involved. Also, the reintroduction of undesirable species is not so easily prevented. Thus it sees that, although it has been done successfully the reclamation of large lakes is not economical in the light of possible future events.

The cost of treating lakes with rotenone has been adequately reviewed in the literature (Vestal 1942; Siegler and Pillsbury 1946). Suffice it to say that the price of powdered derris root has more than doubled since 1942 and labor costs have risen to unprecedented heights.

PHYSIOLOGICAL ACTION OF ROTENONE

Fishes. The actions of a fish under the influence of rotenone was aptly described by Leonard (1939) as follows.

" . . . The first discernible indication that the poison is felt by a wild, erratic, and apparently uncontrolled dashing and plunging. The fish moves at top speed, throws itself blindly against the aquarium walls, and swims on its side or back almost as frequently as in the normal position. This flurry, which may last from five to thirty seconds, usually takes the fish to the surface, where it breaks water repeatedly. The seizure terminates in a convulsive stiffening of the body, accompanied by uncoordinated twitching of the fins and tail. In this condition the fish drifts slowly to the bottom of the tank, where it comes to rest on its side. Here it may lie from two to ten seconds with no movement other than a spasmodic fluttering of the operculum . . . " Follow-

ing this there are occasional returns to activity and death ensues after various periods of time. In addition to reactions mentioned above, there is a gasping and gulping of air by the poisoned fish throughout the performance.

The narcosis resulting from the action of rotenone on fish has been attributed to the effects of the drug on various organs. The account by Rumph (1747) in which he stated that the fish drove to the surface in a dazed condition, not because they ate the alkaloid, but because the sap of the plant made their eyes smart, is obviously based on fancy. Van Hasselt (1911) attributed death in treated fish to stoppage of the heart and the fact that the drug altered the contractions of the bladder.

The majority of workers agree, however, that respiratory failure is the cause of death. Campbell (1916) reported that death was due to paralysis of the respiratory center in the medulla oblongota. Haag (1931), Daneel (1933), and Scheuring and Heuschmann (1935) found that there was a breaking down or histolysis of the gill epithelium with a consequent suffocation of the fishes thus treated. It is of interest to note that all of the above-mentioned workers used concentrations of rotenone that were considerably higher than the minimum lethal dose.

Evidence that histolysis of the gill epithelium is not the primary cause of death is offered by the findings of Hamilton (1941). Using the minimum lethal dose of 0.5 p.p.m. suggested by Leonard, Hamilton found that the effect of rotenone as a respiratory poison for fish was due to vasoconstriction. The diameter of the normal blood capillaries in the gills of fishes is just sufficient to allow the passage of erythroyctes in single file. In a rotenone-treated fish, however, those capillaries were shrunk to a diameter which would not allow the passage of the oxygen-bearing red blood cells.

Thus, the suffocation is due, not to an histolysis of the gill epithelium, but rather to a cutting off of the branchial circulation. The histolysis of the gill membrane apparently follows the vasoconstriction inasmuch as such a condition is present shortly after death in most rotenone-treated fish.

Leonard (1939) using the pumpkinseed (*Lepomis gibbosus*) as a test animal, stated that once a fish lost its equilibrium it was doomed even though transferred to fresh water. That observation is not in agreement with the findings of other workers. Smith (1940) found that in certain experiments trout which had lost their equilibrium revived when placed in untreated water and apparently regained their normal condition. Vestal (1942) observed that of a total of 254 trout rescued from Gull Lake, California, following its treatment with timbo, 78 survived after having been placed in hatchery troughs supplied with cold, well-aerated water. Hamilton (1941) in studying the physiological effects of rotenone on fishes by exposure to sublethal concentrations wrote: "... The animals may exhibit, for hours, the most acute respiratory distress, such as swallowing air and loss of equilibrium, but eventually will recover as soon as the rotenone has decomposed sufficiently ..." On April 26, 1942, Dr. A. S. Hazzard and the the writer treated a small privately-owned trout pond in Oceana County, Michigan. Nearby there was a small

spring-fed holding pond that afforded an ideal opportunity to ascertain whether or not the poisoned fish could be revived from their narcosis when transferred to pure water. Accordingly, 11 brook trout, 9 brown trout (*Salmo trutta*), 4 common suckers (*Catostomus commersonnii*), 2 pumpkinseeds, 2 bluegills (*Lepomis macrochirus*), 6 golden shiners (*Notemigonus crysoleucas*), and 3 bullheads were rescued from the treated pond at the first signs of distress, were marked by clipping a fin, and placed in the untreated spring pond. That evening, 5 hours after being transferred to the pond, most of the fish were apparently fully recovered. On May 17 the holding pond was drained by the caretaker and the following fish were removed: 11 brook trout, 7 brown trout, 4 common suckers, 2 pumpkinseeds, 2 bluegills, 3 golden shiners, and 2 bullheads. All of those fish were reported by the caretaker to have been in good condition. From these findings it is obvious that if fish are rescued at the first signs of distress and transferred to cold, fresh water, they can be revived.

Certainly if death in rotenone-treated fish were due to a destruction of the gill epithelium such revival from the effects of the poison would indicate a remarkable capacity for the regeneration of such tissue. Thus it seems that the vasoconstriction in the branchial circulation as suggested by Hamilton is nearer the correct answer to this question. In the light of facts outlined here all the obvious reactions of rotenone-treated fish can be explained as follows:

1. Constant gasping and gulping of air. Although there is ample oxygen in the surrounding water (there is no evidence that rotenone depletes the dissolved oxygen); the fish are unable to utilize it because the passage of the oxygen-bearing red blood cells has been effectively blocked by constriction of the capillaries in the gills.

2. Loss of equilibrium. The cessation of the passage of the red blood cells cuts off the supply of oxygen to the brain with a consequent loss of function of the organ of equilibrium.

3. Fish can recover fully from the effects of rotenone narcosis. If stoppage of the heart or histolysis of the gill epithelium were the actual cause of death the recovery, if any, could not feasibly take place in a matter of a few hours.

It has long been known that some species of fish are more resistant to the effects of rotenone than others. Wray (1892) mentioned that 1 p.p.m. of the native extract of *D. elliptica* prepared by the Malayans would kill fish in a quarter to a half hour depending on the species treated. Harris (1925) in his account of tuba fishing on the Perak River reported that the drug did not affect all species of fish alike. Leonard (1939) found that the mud minnow (*Umbra limi*) and the goldfish were more resistant than six other species tested. Further, it was evident that the common sucker, bluegill, and pumpkinseed were about equally tolerant but in turn were more resistant than the golden shiner or brook stickleback (*Eucalia inconstans*). Smith (1940) reported that the following 4 species were progressively less resistant to derris: common sucker, lake chub (*Couesius plumbeus*), killifish (*Fundulus diaphanus*) and white perch. It has been mentioned earlier that the bullheads are among the most resistant of the

warm-water fishes.

Invertebrates. Rotenone is both a contact and a stomach poison in insects and is very effective against a wide variety of insect pests (Roark, 1932). Because of such action rotenone has been used primarily as an insecticide. Hamilton (1942) found that rotenone acted uniformly on aquatic invertibrates, causing a gradual narcosis or paralysis. Generally speaking the invertebrates are much less sensitive to the action of the drug than are fish. However microcrustacea are very sensitive to concentrations of rotenone that are lethal to fish.

Higher Vertebrates and Mammals. Early writers described the effects of rotenone on many as very severe. In Borneo it was considered to be a suicidal drug and the Malayans reportedly used it as an abortifacient. More recently it has been shown that oral administration is harmless to mammals, as well as some other vertebrates. Buckingham (1930) made numerous tests on dogs, cats, cows, sheep, and chickens with rotenone and with the ether extract of Derris root and reported no ill effects when administered by mouth in doses up to 0.14 gram per kg. of body weight. He expressed the opinion that larger doses would also be harmless. Haag (1931 was so convinced of the harmlessness of the drug after using it on dogs, cats, rabbits, guinea pigs. etc., that he swallowed 150 mg. (equivalent to 2.3 grains) without experiencing any ill effects. Birdsall (1933) and Leonard (1939) mentioned that continued inhalation of derris dust sometimes caused headaches and irritation of the respiratory passages. Such irritations usually pass off shortly after exposure has been discontinued. Leonard suggested protection by using a nose mask of folded cloth. Vestal (1942) found that a concentration of derris root and water of 1:100,000 had no harmful effects on a garter snake after repeated immersions in the solution over a period of 3½ hours. Also similar and slightly stronger concentrations had no deleterious effects when force fed to a Brewer blackbird, 2 sagebrush chipmunks, a golden-mantled ground squirrel and a domestic sheep. On two separate occasions Vestal drank a cupful of Derris suspension of a concentration of 0.5 p.p.m. and 0.75 p.p.m. without any discomfort.

Field observations by the writer, after having seen Muscovy ducks, redwing blackbirds, cardinals, song sparrows, hogs, cattle, and other vertebrates drinking the water from Derris-treated ponds without any apparent ill effects have led to the opinion that the drug is harmless to vertebrates in the dosages used in fisheries management. Further, the writer has not experienced any discomfort from handling large amounts of Derris powder in the field.

Aquatic Vegetation. Vestal (1942) reported the *Nitella, Potamogeton, Spirogyra,* and some other green algae were unaffected by a concentration of rotenone of 1:100,000 after 4 days exposure. Experience in the field by the writer has indicated that concentrations of rotenone that are lethal to fish will not harm any submerged or emergent aquatic vegetation.

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THE WILDLIFE SOCIETY

Report of the Business Meeting of the Council

The annual business meeting of the Wildlife Society Council was called to order at 8:15 P.M., March 7, 1948, at the Jefferson Hotel, St. Louis, Missouri. The following business was discussed and acted upon:

In the interest of professional solidarity, it was agreed that other organizations of professional wildlife biologists should be encouraged to affiliate with the Society as Sections in accordance with Article VII of the Constitution. It further was agreed unanimously that members of the Sections need not be members of the Society. Collection of dues within and for the Sections, it was thought, however, definitely should be a function of the Sections and should have no connection with the collection of dues within and for the Society.

The petition of the Minnesota Section for affiliation was approved unanimously.

It was agreed unanimously that the desirability of protecting by copyright the names of the Society and its publications should be studied by the Council.

Mr. Douglas E. Wade presented a design for a certificate to be awarded the authors of the articles annually judged the outstanding wildlife publication of the year. It was decided that the Council would give the entire matter further considereation.

Acting on the suggestion of the Editor, it was agreed that the Editor should not be asked to serve as Chairman of the Awards Committee.

Dr. Charles A. Dambach requested that due to the pressure of other duties, he be permitted to resign as Editor of the Newsletter. It was with regret that his resignation was accepted. Hereafter it was agreed, the Editor of the Newsletter should be so designated in both the Newsletter and Journal.

Dr. Harlow B. Mills was reappointed Editor of the Journal. The new Editor of the Newsletter, it was decided, will be appointed at a later date.

Acting on the suggestion of Mr. W. L. McAtee, the Council approved the policy of including the names of Life Members within the regular membership list, provided that some suitable designation therein indicates their status.

Dr. William E. Ricker was appointed to the Membership Committee to fill one of the vacancies caused by the expiration of the terms of Mr. Clarence M. Tarzwell and Dr. Leonard W. Wing. The other vacancy will be filled by later Council action.

Council action in filling the trusteeship now held by Mr. Herbert L. Stoddard will be taken at a later time.

An offer of the Wildlife Management Institute, through Dr. Ira Gabrielson, was gratefully and unanimously accepted. This offer provided for the publication of an index to the Wildlife Review provided that the index be prepared by the Society. The Council further acted for the Society to assist this project by making available a sum of about $100, if needed, for clerical help and supplies.

The Council approved the policy of including unusually long articles in the Journal provided that the Society be reimbursed the cost of such publication. It was further approved that any article would be published in the Journal at a date earlier than would usually be possible, if the Society is reimbursed the entire cost of such publication. In either case, it was specified that all papers must meet the usual high standards for publication in the Journal and that all such articles are to be considered additional and are to be included beyond the usual size of the issue.

After considerable discussion, it was agreed unanimously to refrain, at this time, from accepting an invitation to affiliate the Society with the American Institute of Biological Sciences at a proposed annual cost of one dollar per Society member. The Secretary was instructed to express to the Institute that the Society is sympathetic to the concept of unification of the professional biological organizations for some purposes. It was felt, however, that the reasons for the high cost of membership, plans for alleviating financial hardship among persons who are members of several biological societies, and statements of more concrete objectives should be expressed by the Institute before further action is taken by the Society.

The Editors submitted budget estimates for the next year of $600 for the Newsletter and $4,800 for the Journal. These sums approximate those in the 1947 budget. These budgets and the complete Treasurer's report were accepted unanimously by the Council.

By unanimous vote, it was agreed that the name of the Honorable Frederic C. Walcott by submitted to the membership at the annual business meeting for consideration as an Honorary Member of the Society.

NEW ACTIVE MEMBERS

Harold E. Alexander	James S. Lindzey
Donald R. Ambrosen	Donald Y. McBeath
Lee W. Arnold	Harry T. Maltby
Gerald F. Baker	Ernest G. Marsh, Jr.
Thomas S. Baskett	A. C. Martin
Elizabeth B. Beard	George H. Means
Wendell Bever	A. J. Nicholson
Fred R. Cagle	Carl R. Noren
Milo L. Cox	Clyde P. Patton
Jack C. Culbreath	William L. Preno
Frederick H. Dale	Elmon Radway
Harry J. Figge	Danbar Robb
H. Dean Fisher	Chandler S. Robbins
Henry S. Fitch	Travis S. Roberts
Robert H. Gensch	George A. Rounsefell
Seth Gordon, Jr.	Carl D. Shoemaker
James E. Grasse	Joseph J. Shomon
Gordon Gunter	G. F. M. Smith
William L. Hamnett	Tarleton F. Smith
Edward B. Hill	David L. Spencer
Donald F. Hoffmeister	Frank W. Stanton
Leon W. Hornkohl	Harold Steinhoff
Robert H. Johnson	Ward E. Stevens
James W. Johnston, Jr.	William H. Stickel
	Harold T. Stultz
J. L. Jorgensen	Clarence M. Taube
Louis A. Krumholz	Daniel F. Tillotson

The meeting was adjourned at 11:50 P.M.

LOGAN J. BENNETT, *President*
GEORGE A. PETRIDES, *Secretary*

MINUTES OF THE ANNUAL MEETING

The twelfth annual meeting of the Wildlife Society was called to order by President Logan J. Bennett at 7.20 P.M., March 8, 1948, at the Hotel Jefferson, St. Louis, Missouri. About 200 people were in attendance.

Reading of the minutes of the 1947 meeting was dispensed with since they were printed in the Journal for July, 1947. The Secretary's report was presented and accepted. The Treasurer's report was read by Dr. Paul Dalke and accepted.

The annual reports of the Regional Representatives were given. Region I Representative Allan T. Studholme advised that a northeastern states' conference was held in February, at which time it was proposed to reactivate the New England Section as the Northeast Section of the Society. Mr. Verne E. Davison, Region II, reported briefly on the southeastern states regional conference of administrators and technicians at St. Petersburg, Florida, November 3–5, 1947, and on the recent organization of the Virginia Section of the Society. From Region III, Dr. Warren W. Chase presented a report indicating that the more than 400 members in that Region are extremely active. The Midwest Wildlife Conference held at Lafayette, Indiana, on December 9–11, 1947, he said, was a great success. A Minnesota Section of the Society has been formed and Dr. William Marshall was delegated as its representative at this meeting of the Society.

Mr. E. R. Kalmbach, Region IV, presented news notes on the activities of members in his region. No meetings were held there because of the distances involved. In Region V, Mr. W. C. Glazener reported that because of the great area included, the four states in this region had decided to hold separate meetings in connection with the regular conventions of other established scientific groups. In Texas, Mr. Glazener organized a wildlife session as a portion of the Texas Academy of Science meetings in December, 1947. Drs. Paul R. Needham and Ian McT. Cowan, Representatives from Region VI and VII, respectively, were unable to attend the Conference.

The several Sections of the Society were represented at the meeting. In addition to the preceding comments by Messrs. Verne E. Davison and W. C. Glazener for the Virginia and Region V Sections, respectively, Dr. William B. Marshall and Mr. Philip Barske spoke briefly. Dr. Marshall, representing the new Minnesota Section reported on two organization meetings in Minneapolis and stated that seminars and general open meetings are planned. Mr. Barske advised that Mr. George W. Davis has been named Chairman of the Northeast Section and that another regional game conference is planned for next year.

Temporary auditing and Resolutions Committees were appointed. Mr. Frank C. Edminster, Chairman, Mr. Walter A. Gresh and Dr. Lee E. Yeager were appointed to the former and Dr. Henry S. Mosby, Chairman, Dr. William H. Marshall and Mr. James O. Stevenson to the latter group.

The report of the annual Council meeting was read. It is published in this issue of the Journal.

Dr. P. F. English, Chairman of the Membership Committee, commented on the continued growth of the Society. He offered the Committee's encouragement for Associate Members who have increased their experience and education to apply for Active status.

Dr. Durward L. Allen, Chairman of the Committee on Arrangements, commended the cooperation with the Committee of Mr. C. R. Gutermuth, Dr.

Edward H. Graham and Mr. William J. Howard and the several session Chairmen and Cochairmen.

The announcement of the article judged to be the outstanding wildlife publication of the year was made by Dr. Harlow B. Mills, Chairman of the Awards Committee. This honor went to the New York Department of Conservation representing the several authors and collaborators of the fine study: "The Ruffed Grouse—Its Life History, Propagation and Management."

A report of the Committee on Employment was given by Mr. Robert M. Rutherford, Chairman. He indicated that 178 men will be graduated with a degree in wildlife biology this summer. Roughly 80 per cent will be B.S. degree graduates, about 15 per cent M.S. students and five per cent will be awarded Ph.D degrees. Further meetings of the committee were scheduled, he related, to discuss the present employment outlook for these men.

Mr. John Pearce, Chairman, submitted a report of the Committee on Constitutional Revision which was referred to the Council for consideration.

Due to the sudden illness of Dr. George O. Hendrickson, Chairman of the Professional Standards Committee no formal report of the work of that group was presented. Dr. Samuel A. Graham of the Committee indicated that progress has been made, however, in compiling recommendations for strengthening university curricula in line with the determined actual duties of university graduates now employed as wildlife technicians. Some attention, too, has been given to the preparation of a code of professional ethics.

The report of the Program Policy Committee was presented by its Chairman, Dr. Walter P. Taylor. The several fine suggestions of the Committee resulted in some spirited discussion. It was stressed particularly, that the vitality of the Society would be enhanced by more open discussion of the policies of the Society through "letters to the editor," submitted by the membership and published in the Newsletter.

The Chairman of the Newsletter Committee and Editor of the Newsletter, Dr. Charles A. Dambach, read the report of his committee but, because of the pressure of added responsibilities, was obliged also to submit his resignation. By unanimous vote by the Council at its business meeting, the Secretary offered a resolution expressing the great appreciation of the Society for the fine work done by Dr. Dambach in this capacity during the past several years.

Dr. Danial L. Leedy presented the report of the Journal Index Committee. This Committee, it was disclosed, hopes to complete the index to the first ten volumes of the Journal by this summer under a $100 grant of the Council. At this point, the President acted for the Society to publicly commend the Transactions Index Committee, composed of Dr. Lee E. Yeager, Chairman, and Messrs. John M. Anderson, E. J. Koestner, and Willet N. Wandell, for their excellent work in compiling the index which appeared in the Transactions of the 12th North American Wildlife Conference. With the appointment of a committee to prepare an index to the Wildlife Review (see the Minutes of the Council Meeting in this issue), three very worth-while projects will be in progress or completed by the Society.

Mr. Frank C. Edminster reported for

the Auditing Committee, finding that the Treasurer's records were in good order. Since the Society's books have not been officially audited since 1941, however, it was recommended that this be accomplished early in the term of office of the next succeeding Treasurer.

The reports of all committees were accepted except as otherwise indicated above.

Dr. Henry S. Mosby, Chairman of the Resolutions Committee, read the following Resolutions prepared by that group. All were approved unanimously.

Number 1

WHEREAS the substance of resolution #3 of the 1947 meeting of the Wildlife Society is still of primary importance to the nation, and

WHEREAS much of the best wildlife habitat of the Western States is to be found on Federal lands, and

WHEREAS these lands offer many opportunities for study, restoration and management of wildlife resources, and

WHEREAS the Federal conservation program has been aimed at the adjustment of grazing and other uses so that the soil and water relations can be kept in balance and all public values protected,

THEREFORE, BE IT RESOLVED that The Wildlife Society deplores the program of strong elements of the western livestock industry to gain exclusive use or control of these lands which they are now grazing under permit, or desire to graze, and the Society reiterates its belief that these lands must not be passed on to the control or ownership of any one class of users but must be managed in the public interest, and

BE IT RESOLVED that the officers of the Wildlife Society be instructed to reiterate the previous stand of the Society by submitting copies of this resolution to members of appropriate Congressional Committees.

FURTHER BE IT RESOLVED that the Secretary of Agriculture be commended for his stand on these problems and that he be sent a copy of this resolution.

Number 2

WHEREAS federal aid in fishery work is needed to stimulate fish habitat improvement work and research, and

WHEREAS much of such environmental improvement work is also of great value to wildlife conservation, and

WHEREAS the Dingle Bill, H. R. #1692 is at present before Congress,

BE IT THEREFORE RESOLVED that the Wildlife Society approve the principles of the Dingle Bill and urge its enactment into law by the Congress and that the Secretary be directed to express these sentiments to the proper committee authority of the Congress.

Number 3

WHEREAS the Quetico-Superior International Peace Memorial Forest is of primary value and unique interest to the nation as a primitive recreational area,

BE IT RESOLVED that the Wildlife Society urges the U. S. Congress to expedite passage of resolutions S. 1090 and H. R. 2642 to complete the aquisition program of the U. S. Forest Service in the Superior National Forest to save for all time this last remaining wilderness area and that the Secretary be instructed to transmit this resolution to the appropriate Congressional Committee.

Number 4

WHEREAS the present officers of the Wildlife Society have labored long and brilliantly in carrying out their official duties,

BE IT RESOLVED that a vote of confidence and appreciation for their efforts be extended these officers individually and collectively.

Number 5

BE IT RESOLVED that The Wildlife Society extend to the Wildlife Management Institute, The Chairman, E. R. Gutermuth and members of the Program Committee of the 13th North American Wildlife Conference and the Hotel Jefferson of St. Louis, Missouri, sincere appreciation for facilities and courtesies extended to it and which permitted the successful meeting of the Wildlife Society at the 13th North American Wildlife Conference.

Dr. William E. Ricker was unanimously elected to fill a vacancy in the Membership Committee. After some discussion, a motion to accept the invitation extended the Society by the American Institute of Biological Sciences to join them at a cost of one dollar per member per year was tabled.

By unanimous acclaim, the Honorable Frederic C. Walcott was elected an Honorary Member of the Society in recognition of his many years of service in the cause of wildlife conservation.

In the interest of efficiency, it was approved in principle that committee reports and resolutions prepared by the Resolutions Committee be mimeographed prior to the business meeting and made available to the membership at the start of the Conference. It was further approved that a Terminology Committee be appointed by the President to standardize wildlife nomenclature in accord, where possible, with the standardized nomenclature recommended by related recognized scientific organizations.

The meeting was adjourned at 10:00 P.M.

LOGAN J. BENNETT, *President*
GEORGE A. PETRIDES, *Secretary*

REPORT OF BALLOT COMMITTEE

The Committee audited the nomination and election ballots for The Wildlife Society for 1948–49 and found the following:

1. *Nomination Ballots.* Nominated for *President*: Warren W. Chase and Tracy I. Storer; *Vice-President*: Ian McTaggart Cowan and Frank C. Edminster; *Treasurer*: Paul D. Dalke and Neil W. Hosley; and *Regional Representatives: Region 1:* A. T. Studholme and D. W. Allen; *Region 2:* V. E. Davison and C. W. Watson; *Region 3:* W. A. Gresh and W. W. Chase; *Region 4:* E. R. Kalmbach and J. W. Kimball; *Region 5:* W. C. Glazener and W. P. Taylor; *Region 6:* J. W. Moffett and D. I. Rasmussen; and *Region 7:* C. H. D. Clarke and I. M. Cowan.

2. *Election Ballots.* Results: *President:* Tracy I. Storer; *Vice-President:* Ian McTaggart Cowan; *Treasurer:* Paul D. Dalke; and *Regional Representatives: Region 1:* Allan T. Studholme; *Region 2:* Clarence W. Watson; *Region 3:* Walter A. Gresh; *Region 4:* E. R. Kalmbach; *Region 5:* Walter P. Taylor; *Region* 6: James W. Moffett; and *Region 7:* C. H. D. Clarke.

We find the above correct and final as of April 28, 1948.

CHARLES A. DAMBACH
WILLIAM D. LAWSON
DANIEL L. LEEDY

BRIEFER ARTICLES

IMPROVEMENTS IN EFFICIENCY IN HARVESTING SMARTWEED SEED

Harvesting the seed of largeseed smartweed (*Polygonum pennsylvanicum*) has long presented a problem. Recent developments, however, have greatly increased the efficiency and economy of collecting and storing this important source of waterfowl food and cover, hence making more of it available for planting on refuges and other management areas.

The problem lies in the way the seeds grow and mature. They occur on a cylindrical, upright spike and do not mature uniformly. Mature seed, green seed, and blossoms in full bloom may all be found on the same seed-head or spike. Even when a spike contains a maximum number of mature seeds, they are enclosed within blossoms still green and succulent, while the leaves and stems are still green. Yet the maximum yield is obtained when the plant is in this condition.

The small combines used in harvesting are designed to separate fully ripened seed through a method whereby the heavier ripe grain is knocked out between a revolving cylinder and a rasp-bar. It is then run through a series of screens in an air blast which blows out the lighter materials. However, a difficulty with smartweed is the separation of the mature seeds from blossoms, macerated stems, leaves, etc., since all are of approximately the same weight. Furthermore, as these green parts pass through the machine, juices are extracted which tend to create a gummy mass very difficult to clean and dry. Decomposition and heating are rapid, and very careful handling is required to prevent the seed from losing much of its viability.

The large demand for this seed throughout the federal refuge system and a growing demand among the state conservation agencies have made improved harvesting methods desirable. The availability of large amounts of seed on periodically flooded lands in northern Missouri has resulted in intensive harvesting efforts in the vicinity of the Swan Lake National Wildlife Refuge, which has supplied a large proportion of the seed used on other refuges throughout the United States. The difficulties encountered have stimulated development of vastly more efficient combining methods. These improvements involve radical changes in machine adjustment.

In the past, combine cylinders were so adjusted that they separated the green blossoms enclosing the seed from the seed-heads. The blossoms were literally picked from the head during repeated trips through the machine, just as is done with small grains, and many pieces of stem and leaves were unavoidably included in the end product, Difficulties and delays were experienced when such material refused to run through the elevators and clogged the machine. The partially cleaned seed was transferred to a truck, hauled to a drying platform, and spread to a depth of about three inches to facilitate drying and prevent heating. Here it had to be stirred three times each 24 hours for about five days, after which it was dry enough to re-clean and store. The huge volume of material to be hauled and spread required the constant presence of a truck with each combine. One full day's harvest from each combine required approximately 800 square feet of floor space for drying; and when floor capacity was reached, combining had to be suspended. Moreover, much seed was shattered and lost in the field when the limited capacity of the drying floors prevented continuous harvesting. Using this method, the average yield was three bushels per acre and the average cost 5.5 cents per pound.

During the 1947 harvest conducted by the Missouri Conservation Commission and the U. S. Fish and Wildlife Service in Chariton County, Missouri, an experienced combine operator who was harvesting seed for the Missouri Commission hit upon a combine adjustment that delivered seed direct from the field in a reasonably clean condition. Following this discovery, the State Conservation Commission utilized the improvement to harvest 12,000 pounds of seed with two combines in four days. The U. S. Fish and Wildlife Service, operating on a larger scale,

tested this method with five different makes of combines, further reduced the content of inert matter, and increased the yield per acre. At the same time, the volume of material was reduced from 9.0 bushels of mixed seed and debris per acre to 3.6 bushels of clean seed only, and the danger from heating was materially lessened. The cost of seed dropped from 5.5 cents to 2.7 cents per pound.

The primary requirement in the new method is adjustment of the cylinder in relation to the rasp-bar. The cylinder clearance which proved most satisfactory is ¾ inch; cylinder speed is fast, about 1,200 RPM. These two adjustments must be made very carefully and it is necessary to experiment until exactly the right combination is obtained. Much better results are obtained with machines which have rubberized rasp-bars. The shaker screens should be very nearly or completely closed to prevent leaves and pieces of stem from passing back through the machine. This is necessary to avoid the gummy condition created by excessive juice. A bottom finishing screen, like that used for lespedeza, gives the best results in certain types of combines, although satisfactory results may be obtained with other types oy removing all bottom screens. The air blast should be set as slightly less than the open setting used for wheat and can be regulated in accordance with the amount of good seed blown over into the straw. This is easily discovered by examining the discharge ends of the shaker screens.

The basic change in the entire operation is that the new method rubs out *all* of the seed the first time it passes through the cylinder. This is accomplished by the high cylinder speed and the yielding, rubbing action of the rubberized rasp-bar set up close to the cylinder. Once this operation has been accomplished, the blossoms, green seed, and other green material must be passed out of the machine immediately. This is the reason for closing the shaker screens. Where a lespedeza bottom screen (or finishing screen) is used, the few blossoms that come down from the shaker screens above are screened and blown out, leaving nothing but clean seed to go to the elevator.

Cleaning the seed in the field makes it possible to deposit each hopperful on a tarpaulin without danger of decomposition, as the green material accompanying the earlier product was the chief source of heating. At the end of the day's combining, the seed may be picked up and hauled to the drying floor. If the floors are indoors, the seed should be spread to a depth of about three inches and should be raked or stirred once a day for five days. After the seed dries, another layer may be added and floor space used much more efficiently. The use of platforms in the open reduces drying time almost by half.

With proper combine settings, the reduction of material to be handled and the simplification of the drying process save trucking and drying costs, while increasing harvested acreages and yield per acre.—HERBERT H. DILL, *Swan Lake National Wildlife Refuge*, AND GUY A. GREENWELL, *Missouri Conservation Commission.*

"HUNTER MANAGEMENT" WITH MULTIFLORA ROSE

A practical use for multiflora rose which evidently has not been recognized appears to this author to merit the consideration of farm planners and agricultural wildlife technicians.

For many years nurserymen in this country have used the root system of *Rosa multiflora* as budding stock for less hardy roses. In the late thirties, at Elsberry, Missouri, the Nursery Division of the Soil Conservation Service found that this shrub had practically all of the qualities desirable in a living fence. Since then, land owners working with Soil Conservation Service biologists and farm planners have given it widespread trials in the midwest and northeast which have proved its worth for erosion control and wildlife cover as well as for pasture fences.

A multiflora fence is about 8 feet high and 8 to 12 feet wide when mature. It will turn any kind of stock, even hogs if they are

ringed. It is site-tolerant, although it grows best on good soils and responds well to fertilization. It does not spread objectionably. A fence is established by planting seedlings a foot apart in a well-prepared bed and mulching or cultivating the first year.

There are many areas in this country where farmer-sportsman relationships have deteriorated sadly owing to habitual trespass by an unscrupulous minority among the hunting public. It is likely that on many farms the planting of living fences of multiflora rose on all *boundary fences* would completely change this picture.

Neither hunters nor their dogs will penetrate such a fence. Entrance to a farm will be possible only through the barnyard, with the owner's permission. This is no hardship to the respectable sportsman. Rather, it is an advantage, since it will be easy for him to keep from wandering onto a neighboring property. Under these conditions the hoodlum hunter will be forced to mend his ways or go elsewhere. If there are other gates on the farm, the fences will still enable the owner to intercept trespassers easily if any enter by such means.

On some farms there will be barriers to the establishment of an unbroken fence. Marsh areas, streams, and the shaded borders of woodlots will present difficulties or necessitate an interruption of the multiflora. Such breaks might not impair trespass-control values of the fence if adjacent farms are inclosed in this way.

This idea has appealed to farmers with whom the writer has discussed it. In many areas it will be a good selling-point in getting multiflora onto the land. Such a fence completely around a farm will provide both a large amount and good distribution of wildlife cover and will be a particularly good rabbit management measure. It is also a relatively simple procedure and should appeal as a project to sportsmen's groups. There is a possibility here for cooperative arrangements whereby a part or all of the costs of shrubs could be borne by the sportsman in return for hunting privileges.

The use of this shrub on farm boundaries seems to be one of the most direct and practical ways to improve farmer-sportsman relationships and carry out an effective wildlife management measure at the same time. This could hardly fail to result, even if a farmer's main interest was in pasture fences—DURWARD L. ALLEN, *U. S. Fish and Wildlife Service, Laurel, Maryland.*

ADAPTABILITY OF BROOK TROUT

Lakes and ponds with borderline oxygen and temperature ratings for trout often produce perplexing problems for our biological survey crews. Seldom do we recommend the stocking of brook trout (*Salvelinus fontinalis*) in a pond in which water is warmer than 72°F, and in which the dissolved O_2 content drops below 5 parts per million. This, I believe, with minor variations is a standard practice in most of the states. Experience has repeatedly shown us that fish stocked in such waters will often die at the time of stocking.

Data are however gradually being accumulated to show that fish which are stocked under optimum conditions can adapt themselves to temperatures and dissolved O_2 which are lethal under ordinary conditions. Jahoda (1947) found trout which survived in water of 52°F containing only 1.1 p.p.m. of oxygen. Our survey crew found a healthy trout population in a pond with supposedly lethal conditions.

Copp's Pond in Melvin, New Hampshire, was created in 1944. It is a shallow, marshy pond with a surface acreage of approximately thirty acres and a maximum depth in summer of seven feet. The pond is stocked with fingerling or legal brook trout in the autumn months, or immediately after the ice breaks up in spring, and has become one of the best trout ponds in the region. A routine chemical survey was made of the pond on August 25, 1947. Had our survey crew obtained the results listed in the following readings, before the pond was stocked, Copp's Pond would

Depth	*Temp.*	pH	O_2 *p.p.m.*	O_2 *% Sat.*	CO_2
0′	86°F.	6.4	7.7	*102.91*	6.0
4′	78°F.	6.2	4.0	*49.16*	11.0
6′	77°F.	6.2	3.1	*37.74*	13.0
7′	68°F.	—	0.9	*10.00*	—

have been classified as a warm-water fish pond, and unsuitable for trout. The only water with temperature considered suitable for trout, 68°F at the 7 foot level, had but .9 p.p.m. of O_2. A gill net was then placed in the area where the readings were made. Four trout and one sucker, all in good condition, were caught within two hours.

Data such as these now lead us to believe that trout stocked in the late autumn months can adapt themselves to various temperatures of our southern New Hampshire lakes which to date have been listed as unsuitable.

LITERATURE CITED

JAHODA, W. J. 1947 Survival of brook trout in water of low oxygen content. Journ. Wildl. Mgt. **11**: 96–97.

—HILBERT R. SIEGLER, *Fish and Game Department, Concord, New Hampshire.*

ANIMALS THAT EAT PONDEROSA PINE SEED

A good opportunity to observe the eating of ponderosa pine seed by different animals presented itself during the early fall of 1947 at the Boise Basin Branch Station of the Intermountain Forest and Range Experiment Station near Idaho City in central Idaho. The station is located in a stand of 80-year-old second growth ponderosa pine, some trees of which bore a medium to heavy cone crop and attracted animals as a food source.

Feeding of consequence started September 10, reached greatest activity about the first week in October and tapered off toward early November. In addition to the red squirrel (*Sciurus* sp.), the chipmunk (*Eutamias* sp.), and the Great Basin white-footed mouse[1] (*Peromyscus maniculatus sonoriensis* (LeConte), birds were observed to be active during the 2-month period. These included the house finch[1] (*Carpodacus mexicanus*), the redpoll (*Acanthis linaria*), the red crossbill (*Loxia curvirostra*), Clark's nutcracker (*Nucifraga columbiana*), the white-breasted nuthatch (*Sitta carolinensis*), the red-breasted nuthatch (*S. canadensis*), the white-headed woodpecker *Dryobates albolarvatus*), Steller's jay (*Cyanicitta stelleri*), and the black-capped chickadee (*Penthestes atricapillus*).

The finches were the first birds observed feeding; they came in flocks of 15 to 40 individuals from early September to mid-October. Most of their feeding was spasmodic and was done while perching, although early morning feeding was done on the ground, which was littered with freshly fallen seed. Redpolls were observed once in a small flock, but remained for some time in one tree working it thoroughly before moving on to another one. Nutcrackers, usually single birds but sometimes in groups of 5 or 7, were busy during the entire period as were the nuthatches. The red-breasted nuthatches were more common than the white-breasted and, like the nutcracker and white-headed woodpecker, they secured seed from all parts of the cones. The most voracious eaters, however, and those which worked the cones most completely (and obviously ate the most seed per bird) were the crossbills which were present in largest numbers in the middle of October. In flocks as large as those of the finches, these birds searched out the seed methodically, using their bills to move themselves parrotlike to the under side of the cones when eating. Observations were made only once on both the chickadee and Steller's jay, though the latter appeared to eat fallen seed on the ground on several occasions. Cassin's purple finches (*Carpodacus cassini*) have been observed to eat sown seed in the field nursery surrounded by virgin forest some 5 miles from headquarters.

While largely of academic interest, these observations confirm the fact that many species of animals consume sizable quantities of ponderosa pine seed both in the trees and on the ground. In a region where many factors militate against the successful establishment of both natural and artificial regeneration to an extent where a "catch" of seedlings is an event of great interest to conservationists, this is one more reason

[1] Identification by Dr. D. J. Obee, Dept. Zoology, Boise Junior College.

which explains the slowness of nature in replacing a forest cover. In a heavy seed year, the feeding by animals would probably be of little consequence but in a year of poor or medium seed production, animals could account for a large proportion and could be responsible for preventing welcome establishment of forest reproduction should such a dispersal of seed be followed by a favorable (wet) growing season.—JAMES D. CURTIS, *Intermountain Forest and Range Experiment Station, Ogden, Utah.*

ONE LOON A VILLAIN

When several Fish and Game Department members were on a hunting trip in northern New Hampshire in October, a common loon (*Gavia immer immer*) on Second Connecticut Lake did considerable feeding within a hundred yards of our cabin. For three successive days I saved its life by restraining members of our party from shooting the bird, who argued that loons had no place in trout and salmon waters. On the fourth day the Department's fish truck arrived with a load of two-year-old salmon. These were planted immediately off shore directly in front of our cabin. During the planting operations the loon suddenly appeared about one hundred and fifty yards from shore. When the last fish had been unloaded we shot the loon. Its gullet contained nine of the salmon.

Our Department estimates the cost of raising these fish at approximately ninety cents a fish. There is no way of estimating how many more salmon this loon would have devoured. In approximately ten minutes of feeding, this loon had cost the State $8.10, eliminated nine of New Hampshire's sportiest and most highly prized fish, and given my efforts at wildlife conservation a severe set-back. Anyone already prejudiced against loons would be apt to overlook the fact that this batch of fish was hatchery-raised and highly concentrated.—HILBERT R. SIEGLER, *Fish & Game Department, Concord, New Hampshire.*

FIVE-YEAR TAKE RECORD ON A NEW MEXICO DUCK MARSH

In 1943 a group of sportsmen purchased a 60-acre tract of water-logged land to be developed as a duck marsh. The area is located one-half mile west of the Rio Grande and 50 miles south of Albuquerque in Socorro County, New Mexico.

At the time of purchase, the area was open to unrestricted grazing by cattle, horses, sheep and goats, and there was practically no duck food available. Water on the area fluctuated, depending on the rise or fall of the river. When the river was low, there were only two to three acres of open water, and when it was high this area was increased to 15 to 20 acres.

In September, 1944, part of the marsh was fenced, but some livestock gained entrance each summer until the fall of 1946 when the entire marsh was fenced. In the fall of 1946 dikes were constructed with outlets to control water level. As a result of no summer grazing, regulated water level, and some planting of wild duck millet (*Echinochloa crusgalli*), the food and water conditions in 1947 were much more favorable to ducks than they were in 1943.

During the five years that we have hunted this marsh, I have kept a record of all ducks killed by members and guests. I present this record for several reasons. It gives an indication of trends in total duck population and population trends of the various species. I also hope that this note may encourage others to keep and publish records of the take on gun club marshes. Such records, if accurately kept, will be of value in connection with our national interest in duck management.

There is no question regarding identification of any of the species except cinnamon teal. There may be some blue-winged teal listed as cinnamon teal since none was in

	1943–44	*1944–45*	*1945–46*	*1946–47*	*1947–48*	*Total by species*
Mallard	22	34	27	25	22	126
Green-winged Teal	23	13	18	8	31	92
Baldpate	56	12	0	12	11	91
Gadwall	17	34	2	7	2	62
Pintail	8	10	3	10	17	48
Shoveller	19	4	4	3	16	46
Scaup	17	1	0	0	1	19
Canvasback	2	3	2	4	1	12
Cinnamon Teal	0	0	0	0	10	10
Redhead	5	0	0	0	2	7
Ringneck	2	3	0	0	0	5
Bufflehead	1	1	0	0	0	3
Goldeneye (American)	0	0	0	0	2	2
New Mexico Duck	0	0	0	0	2	2
Wood Duck	0	0	0	0	2	2
Total take of all species by years	172	115	56	68	119	
Grand Total						527

adult male plumage and identification could not be positive.

Duck seasons in New Mexico during this period were

		Bag limit
1943–44—Nov. 2 to Jan. 10	70 days	10 per day
1944–45—Nov. 2 to Jan. 20	80 days	10
1945–46—Nov. 2 to Jan. 20	80 days	10
1946–47—Nov. 23 to Jan. 6	45 days	7
1947–48—Oct. 7 to 20 and Dec. 23 to Jan. 5	27 days	4

Gun hours on the marsh were very close to the following:

1943–44—246 hours
1944–45—288 hours
1945–46—256 hours
1946–47—240 hours
1947–48—208 hours

Twenty-five different hunters have shot on the marsh but only from three to six hunters at one time and these usual'y only on weekends.

We used retrievers and lost birds were held to a minimum. To the best of my knowledge, only seven downed birds (2 mallards, 3 pintails, 2 teal) were unrecovered in 1947–48. This is a cripple loss of a little less than six per cent.

It will be noted that mallards, green-winged teal, baldpates, gadwalls, pintails and shovellers are our most common ducks and make up a total of 465 out of a grand total of 527 ducks taken in five years. There was a distinct decline in baldpates since 1943–44 and of gadwalls since 1944–45 Mallards, green-winged teal, pintails and shovellers have continued to make up a fair percentage of the take each year.

Ducks were most numerous during the first half of the split season (October 7 to 20, 1947) when we took 78 as against 41 in the last half (December 23 to January 5, 1948). Ducks were more numerous at the opening of the second half of the season, December 23, than they were at the close, January 5. The split season appears to have the advantage of providing a better distribution of kill among the various species. This is demonstrated by the fact that all of the cinnamon teal and baldpates and 15 out of 17 of the pintails were taken during the first half (October 7–20) of the 1947–48 season.

In spite of the fact that there was some improvement each year in food and water conditions in our marsh, there was a decline in take from 1943–44 through 1946–47. The increased take in 1947–48, in spite of the short season, low bag limit and fewer shooting hours, may be laid partially to the improved conditions in the marsh and partially to a greater number of ducks in this locality.

Our take record and my own observations on the marsh and on the drainage canals between the marsh and Albuquerque, indicate that there were more ducks in this section of New Mexico during the winter of 1947–48 than during the previous two seasons.

Although we did not keep a record of the number of American mergansers seen or taken, my observations indicate that there were fewer over our marsh during 1947–48 than during any season since 1943–44.—A. E. BORELL, *Regional Biologist, U. S. Soil Conservation Service, Albuquerque, New Mexico.*

A METHOD FOR TRAPPING MALE RUFFED GROUSE[1]

While engaged in a population study of the ruffed grouse (*Bonasa umbellus monticola*) in central Pennsylvania, under the supervision of Dr. Logan J. Bennett, former Leader of the Pennsylvania Cooperative Wildlife Research Unit, and Dr. P. F. English, Professor of Wildlife Management at The Pennsylvania State College, the authors developed in the spring of 1947 an effective method of trapping male ruffed grouse by use of a mirror in a wire box trap.

The trap was a rectangular box 28 inches, long, 14 inches wide and 18 inches high constructed of electrically welded wire fabric, 1×2 inch mesh; the two sides, the floor, and the roof were formed from one piece of wire fabric by bending it into the desired shape, whereas, the rear wall and the door were of separate pieces of the same material. Three inches below the wire fabric roof a ½ inch mesh gill net was stretched rather loosely across the top of the trap to prevent captured birds from seriously injuring themselves in frantic efforts to escape. Near the middle of the trap about one inch from the floor and extending across its width was a metal rod upon which pivoted a large wooden treadle. A straight metal rod fastened to the rear corner of the treadle extended from its point of attachment, forward to a point above the entrance where it was loosely supported by a staple driven into one of the two slotted wooden posts which serve as guides for the door. The tip of the rod extended just far enough beyond the front edge of the trap to support the door when the trap was set. When the treadle was depressed the rod was pulled from its position, thereby allowing the door to drop freely into place by its own weight, securely closing the entrance. An 8×10 inch mirror, fastened in an upright position to the inside of the rear wall so that its reflecting surface faced the entrance, served as a decoy. The entire trap except the mirror was sprayed with brown paint to make it blend with outdoor surroundings.

During the spring and fall drumming periods, male grouse were captured readily by this kind of trap placed either on the ground with the entrance facing the spot on which a grouse was accustomed to drum or upon the drumming log itself with the trap entrance facing the bird's usual drumming position. No camouflage other than the coat of brown paint was necessary as the grouse appeared to be quite without suspicion.

After being trapped and released the grouse usually avoided the site of its capture for a week or more but later returned to drum at the old location. On several occasions birds that escaped after being trapped were recaptured on the same log a few weeks later.

When the net buffer was used at the top of the trap the captured birds received no injuries other than minor cuts at the base of the bill and slight abrasions at the bend of the wing.

Dr. H. E. Kilgus, a member of the Penn-

[1] Paper No. 50 from the Pennsylvania Cooperative Wildlife Research Unit, U. S. Fish and Wildlife Service (U. S. Dept. of the Interior), The Pennsylvania Game Commission, The Pennsylvania State College, and the Wildlife Management Institute, cooperating.

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sylvania Game Commission, aided materially in devising a workable mechanism for the box trap.—WARD D. TANNER AND GLENN L. BOWERS, *The Pennsylvania State College, State College, Pennsylvania.*

WOLVERINE FUR FROSTING

Furs loom large in the minds of arctic explorers as protection against the elements. The outer garments, or parkas, of many Eskimos are frequently provided with attached hoods which are bordered with furs. It is supposed (John Murdock, 9th Annual Report, Bureau of Ethnology, Smithsonian, 1887–1888, 1892, p. 109) that the fur so framing the face would break the force of high winds somewhat. Whether this is so would have to be determined by actual wearing tests under arctic conditions.

It has been claimed that wolverine fur is the only fur suited for this purpose since it does not frost, i.e. since the moisture of the breath does not accumulate in and adhere to this fur and in turn whip and cut the face. Dr. H. W. Krieger, U. S. National Museum, who has a very large collection of Eskimo garments, observed that many kinds of furs and even feathers were used as borders, the governing principle apparently being the availability of local raw material. To test the theory of differences in the frosting of various furs the Quartermaster Corps and, the Fish and Wildlife Service, United States Department of the Interior, made a study of wolverine fur in comparison with certain more abundant furs and other material for its resistance to frosting.

Samples of fur were cut from the dorsal portion of three pelts, wolverine, wolf, and coyote and from an alpaca pile fabric. These samples were cooled, sprayed with cold water by means of an atomizer and placed in a refrigerator at a temperature of approximately 0°C. After sufficient time had elapsed for the minute droplets to freeze the furs were examined. The alpaca pile fabric was always badly caked with ice. The wolf and coyote furs were matted down and contained chunks of ice. In the wolverine fur ice crystals had formed in the underfur, but the guard hairs were always free from ice. It may be that some of the droplets of water had run down the guard hairs into the underfur; also that some evaporation of the moisture was doubtless facilitated by the separated position of the guard hairs.

In seeking for an explanation for the difference in frosting between the furs the guard hairs were examined microscopically. The wolverine guard hairs possess cuticular scales as do the guard hairs of the other furs; and differences in scalar pattern would not cause this distinct behavior toward frost. However, the guard hairs of wolverine furs are straight, whereas those of wolf fur are curved and of coyote fur even more so. The underfur of wolverine fur is uniformly about one inch long; the long guard hairs, over two inches long, project noticeably beyond this surface. On the other hand, the underfur of the other two furs is characterized by irregularity of outline, hence it tapers off among the projecting hairs. The density of the underfur of wolverine is obviously much greater than that of the other furs and does not incline to mat like the others. Finally the angle of insertion of the fibers in the wolverine skin is much greater than that of the other furs. The combination of the above mentioned characteristics results in the caking of ice in wolf and coyote furs, whereas in wolverine fur the underfur frosts but the guard hairs stand free from each other.

If furs framing the face actually do break the force of high winds, then it should be noted during actual wear whether the frosting of the underfur of the wolverine is objectionable. The consensus is that the available supply of wolverine is very limited; consequently the above data should be of considerable importance in directing the experimental production of a manufactured product.

In conclusion, mention may be made of the manner in which the fur is attached to the hood. This has been observed on a good parka at the National Museum and also was previously described by E. W. Nelson (Eighteenth Annual Report of the Bureau of Amer-

ican Ethnology 1896–97, Part 1, p. 31, 1896–97, 1899):

"These borders are usually made of an outer strip of wolfskin with the long hairs standing out, as before described. Just within this is sewed another belt or band of skin from the wolverine so that the long outer hairs lie back against the wolfskin border, producing a pleasing contrast. These halo like borders, when the hood is drawn up, surround the face and give a picturesque appearance to the wearer."

In other words the fur is sewn on the hood in such a manner that the hair flow is away from the face. Perhaps the outer strip of wolfskin also performs a practical function.—THORA M. PLITT HARDY, *U. S. Fish and Wildlife Service.*

RESULTS OF A VITAMIN A STORAGE STUDY[1]

Due to the current interest in vitamin A investigations the following data are presented (Table 1). During the course of investigations on the role of vitamin A as a survival factor of the bobwhite quail, *Colinus v. virginianus*, livers of various species of animals were spectrophotometrically analyzed for their vitamin A content. The liver was considered to be the major storage organ of vitamin A. Although no comparative data on the vitamin A requirements of these various animals are available, the results are presented for the interest they may create.

Of the animals examined the species containing the largest amount of vitamin A stored in the liver on either a per gram or a total basis was the ruffed grouse, *Bonasa u. umbellus*. This may be the result of consuming green plant material, a major winter grouse food, which is relatively high in vitamin A activity. What appears to be a low

[1] The Ohio Division of Conservation and Natural Resources, the Ohio State University, the U. S. Fish and Wildlife Service and the Wildlife Management Institute Cooperating.

TABLE 1

Species	Date	Collection		Sex	Body Weight (gm.)	Liver Weight (gm.)	I.U. of Vitamin A	
		Locality	Collector				per Gram	per Liver
Bonasa u. umbellus	12/ 4/46	Vinton Co., Ohio.	K. A. Mitchell	M	793.8	7.0	5,157.2	36,110
Falco sparverius	4/ 8/47	Prince George's Co., Maryland.	R. E. Stewart	M	—	2.9	710.4	2,060
Gavia immer	3/24/47	Ocean City, Maryland.	R. E. Stewart	F	—	—	484.4	—
Phasianus colchicus torquatus	11/15/46	Wood Co., Ohio.	E. H. Dustman	M	—	16.8	1,704.8	28,641
Phasianus colchicus torquatus	11/16/46	Wood Co., Ohio.	E. H. Dustman	M	—	15.1	1,407.8	21,258
Phasianus colchicus torquatus	2/25/47	Cuyahoga Co., Ohio.	V. Schultz	F	—	7.7	898.8	6,921
Phasianus colchicus torquatus	2/25/47	Cuyahoga Co., Ohio.	V. Schultz	F	—	8.6	1,197.6	10,299
Phasianus colchicus torquatus	3/ 9/47	Wood Co., Ohio.	E. H. Dustman	F	—	12.0	1,408.4	16,901
Sialis sialis	3/30/47	Prince George's Co., Maryland.	C. S. Robbins	F	—	.9	1,283.4	1,155
Strix varia	April 1947	Prince George's Co., Maryland.	C. S. Robbins	—	—	—	2,189.6	—
Zenaidura macroura	3/ 4/47	Franklin Co., Ohio.	L. G. Webb	M	162.0	2.2	1,450.0	3,190
Zenaidura macroura	3/28/47	Highland Co., Ohio.	L. G. Webb	F	130.8	2.2	1,609.0	3,540
Marmota monax	11/23/46	Athens Co., Ohio.	E. H. Dustman	M	4,592.6	—	2,040.8	—
Ondatra z. zibethicus	11/23/46	Franklin Co., Ohio.	V. Schultz	M	1,013.0	18.5	175.4	3,245
Procyon l. lotor	3/19/47	Prince George's Co., Maryland.	L. M. Lewellyn	F	2,650.0	53.7	363.6	19,525
Procyon l. lotor	3/19/47	Prince George's Co., Maryland.	L. M. Lewellyn	F	2,000.0	48.0	None detected	—

storage on a per gram basis in the muskrat, *Ondatra z. zibethicus*, might be due to the unavailability of foods high in vitamin A activity. This unavailability might be due to the inaccessibility of certain foods resulting from a prolonged ice cover or food predilections. The presence of apparently low storage in the loon, *Gavia immer*, is contrary to the expected condition as their major food item, fish, is generally a good source of vitamin A. One of the largest species examined was the raccoon, *Procyon l. lotor*. Two Maryland raccoons found dead in a box trap were emaciated and one individual contained numerous endoparasites. There was no indication of the presence of vitamin A in the liver of one individual and apparently a small amount, relative to body size, in the other. This suggests that death might have been partially the result of a vitamin A deficiency. The fact that the woodchuck, *Marmota monax*, was in a state of partial hibernation suggests that the amount of vitamin A present in the animal had to suffice until the termination of hibernation. It is realized that various factors such as efficiency of utilization, body requirements and liver weight have to be taken into consideration when analyzing the data.—VINCENT SCHULTZ, *Ohio Cooperative Wildlife Research Unit, Columbus, Ohio.*

PELTING MUSKRATS BY AIR INFLATION

The removal of the skin from sheep by means of air blown beneath the skin layer, with the aid of a reed, has long been practiced in Sicily. This novel method inspired the writers, towards the latter part of the 1946 muskrat trapping season at the Montezuma National Wildlife Refuge, to investigate the possibilities of employing compressed air in a somewhat similar manner to "blow off" or loosen the skin from the carcass of muskrats in order to facilitate skinning. Due to the rush of the large scale trapping and skinning operations, pressure of other research work, and termination of the season, this inflation method could be tested on only 39 muskrats, selected hurriedly at random as they came in from the trap line. The results, although admittedly based on a rather small series, appear to be promising; therefore it seems advisable to present them so that others may experiment with this method of using air-inflation in removing fur skins.

For these tests a long rubber hose with an attached tire valve chuck was employed together with a small welding tip. The latter was inserted in a slit, cut on the upper surface of the hind foot, and the air then quickly applied in the same manner as is done with an automobile tire. An air pressure of about 60 pounds was sufficient to give the inflated animals an appearance of two to three times normal size. Insertion beneath the skin of the foot insured the forced air loosening the skin in such a manner that most of the fat would remain attached to the carcass, enhancing the appearance and marketability of the latter. Use of slits made at the base of the tail, on either of the legs, the head or beneath, usually resulted in much of the fat being removed from the body and being left attached to the skin, thereby necessitating more fleshing.

The first muskrat treated by the air inflation method was a very large 4 pound 7 ounce male on March 4th. As soon as the welding tip was removed, the opening apparently immediately sealed itself. After inflation, this animal appeared as large as a small beaver and was allowed to remain on exhibition in that condition before skinning until the second day. A comparative series of inflated specimens was then run along with animals skinned, fleshed and stretched in the routine manner. It was found that most of the "blown" specimens remained well-inflated for hours unless bites or fighting cuts were present. These animals were skinned, fleshed and stretched by four different operators and the results carefully checked. All were of the unanimous opinion that the inflation process made the skinning noticeably easier, required less fleshing, and resulted in maximum-sized pelts which were uniformly wider in the shoulders and forward portion and averaged three-quarters of an

inch greater in width across the base. The method shortened the length slightly but resulted in pelts of largest possible size and fine appearance. Local fur dealers who examined these pelts, both in the raw and stretched condition, discounted any possibility of over-stretching or pulling apart of the skin and were rather enthusiastic in their comments.

and efficient aid in removing pelts of muskrats and many other animals, especially for the larger operators as small air compressors can be easily installed in the fur house for convenient use. Differences in skin thickness of muskrats in various sections of the country and particularly in the southern States, however, might conceivably greatly alter results with such a method. The time involved in

TABLE 1.—PERCENTAGE DISTRIBUTION BY SIZE OF MUSKRAT PELTS (MIXED SEXES) FROM THE MONTEZUMA NATIONAL WILDLIFE REFUGE, N. Y., FEBRUARY 14–MARCH 17, 1946

Size grade	Routine Method		Air-inflated	
	Number of pelts	%	Number of pelts	%
XXX Large	338	*52.48*	30	*76.92*
XX Large	188	*29.19*	6	*15.39*
X Large	68	*10.56*	2	*5.13*
Large	39	*6.06*		
Large-Medium	1	*0.16*		
Medium	8	*1.24*	1	*2.56*
Small	2	*0.31*		
Totals	644	*100.00*	39	*100.00*

The inflation treated pelts were tagged and numbered, and together with a total of 644 others on which accurate data as to sex, weight, age classification and measurements had been secured as a sample for an analysis of the population (February 14–March 17, 1946), were submitted along with the entire season's catch to the New York Auction Company for grading and public sale. Complete data on the muskrats pelted in the regular or routine manner as against those skinned by the inflation method are given in Table 1.

The air-inflation treatment described appears to offer some possibilities as a practical

removing fur pelts by air-inflation and fleshing as compared with the regular methods of skinning is an important factor to be considered. Efficient trappers can remove a pelt and flesh it so rapidly and satisfactorily that the air-inflation methods must be superior in efficiency or improve the value of the pelt to substantiate the practicability of its application. Further, research on a more comprehensive scale is required before air-inflation can be recommended for general use.—HERBERT L. DOZIER AND MERTON RADWAY, *U. S. Fish and Wildlife Service, Cambridge, Maryland, and Seneca Falls, New York.*

REVIEWS

The Ruffed Grouse, Life History, Propogation, Management. By Gardiner Bump, Robert W. Darrow, Frank C. Edminster, and Walter F. Crissey. New York State Department of Conservation, Albany, New York. xxxvi plus 915 pp., numerous illustr. $10.00.

In any field of investigation progress dictates that occasionally a knot must be tied in the numerous strings of our knowledge, and from this joining-together new departures are made. The present book is a comprehensive treatment of a comprehensive project, initiated in 1930 and reported on to 1946. Its 915 pages are full of information, much of which will be of interest to the sportsman as well as the game technician.

Along with the four authors listed, a number of other workers have contributed parts which add to the completeness of the volume. The writing is good, at times charming, and the printing is excellent. Illustrations are good and add much to the value of the book. The text is well organized, several specific mechanisms being used to make wieldy the mass of data included. There is an index of 19 pages. Each chapter starts with a list of subheadings. This list is followed by a summary, including, in addition to a list of summary sentences (each paragraphed for quick reference), page numbers for quick reference to enlarged discussions in the body of the text. There is an abundance of footnotes, many of them indicating cross reference to other pages where the same subject is dealt with. It will not be difficult to pick out specific facts from the near 1,000 pages in a minimum of time.

The first part on background, basic biology, and economic importance consists of two chapters; the second part, dealing with factors affecting abundance, is divided into 11 chapters; five chapters on management comprise the third part. The fourth, which is called an appendix, uses approximately 200 pages, and will be referred to extensively.

Any worker on ruffed grouse who has gone far into his problem, may take exception to some of the statements included in this book. This is a natural consequence of publication. The present reviewer, who has never worked with this bird, is disappointed at the repeated inference and suggestion, at the many points upon which the reader is left unsatisfied, at the lack of specific statement here and there.

But regardless of future contributions on the ruffed grouse, this book will be a very important source of information for many years to come.—HARLOW B. MILLS.

Wild mammals of Virginia. Charles O. Handley, Jr., and Clyde P. Patton. Richmond, Va., Commonwealth of Virginia Commission of Game and Inland Fisheries. vi+220 pp., 103 figs., 1947.

Handley and Patton's account of the mammals of Virginia well achieves the stated aims of providing a simple, adequate reference for the farmer, hunter, student, and teacher. This book is the outgrowth of one of several studies undertaken or proposed by four cooperating agencies in Virginia to aid in restoring species to depleted areas of the state. All concerned are to be congratulated on the far-sightedness of their proposed program in basic research.

Over half the book contains accounts of the kinds of mammals known to occur (89 species and subspecies) or possibly occurring (an additional 16 kinds) in Virginia. For each, the records of occurrence are plotted on distribution maps and an account of the general distribution in the state is given. Many students will regret that localities from whence specimens have been collected are not recorded. For each kind, distinguishing characteristics, measurements, and habitat information are included. One may doubt the authors' wisdom of including a subspecies, for example *Sciurus niger neglectus*, solely on the basis of unpublished and apparently sight records and without specimens in hand for verification.

The remainder of the book covers such subjects as game mammals, fur bearers, marine mammals, and vanished mammals. One learns in these sections that the whitetail deer, once so common in Virginia, had

been exterminated from the mountainous portion of the state in the early part of this century. Through restocking, conservation, and the establishment of "*dog* laws," now the deer occur commonly in at least 89 of Virginia's 100 counties. Elk, introduced from Yellowstone Park, have increased so rapidly that an open season has been declared.

Much yet remains to be learned about the distribution of mammals and the limits of the geographic races in Virginia. One can not help but regret that more intensive collecting was not undertaken to provide this information before the book was compiled. With the appearance of this book, many students may feel that the problems of distribution and speciation of mammals in Virginia have now been solved. As the authors point out, "this publication is only a beginning," but a good one, indeed.—DONALD F. HOFFMEISTER

NOTE

It is with great regret that we record in this issue the death of Dr. Aldo Leopold, on April 21, 1948. A heart attack brought an end to the career of this thinker and director of wildlife thought and activity, and the loss is felt by the host of people to whom he was not only a person of high professional ability but a warm personal friend. To few people is given the distinction of having as many *friends* as had Dr. Leopold.

While the temptation is great to continue this note, others with greater ability will furnish a suitable memorial for these pages, which memorial will appear at a later date.—HARLOW B. MILLS.

OBITUARIES

CHARLES KNESAL COOPERRIDER
1889–1944

It is one of the ironies of human ecology that if there be a spark of divinity in an individual it is invisible at birth, is mistaken for less important things during his life, and becomes completely visible only after his death.

In my opinion such a spark existed in Charles K. Cooperrider. During the decade that I worked with him, I mistook it for ordinary technical ability, gentle geniality, and extraordinary tolerance and patience. I now realize that these were underestimates; that Cooperrider, as much as any other individual of his generation, created the present ecological concept of "Water, Land, and People." (This was the title of the last published writing in which he participated.) Whether or not we yet realize it, this concept is destined to shape and delimit the destiny of the United States, and of every other country where rain splashes, and where abused soil moves seaward faster than rocks decay.

A new idea is, of course, never created by one individual alone. A prophet is one who recognizes the birth of an idea in the collective mind, and who defines and clarifies, with his life, its meanings and its implications. In this sense Charles Cooperrider was a prophet. He saw that unkindly land-use was leading the Southwest toward disaster, and he devoted his career to the creation of techniques whereby we might use the western lands, and also keep them.

* * *

Cooperrider was born at Brownsville, Ohio, June 3, 1889. He graduated in 1914 from the University of Ohio, where his major studies were biology and chemistry, and where Sigma Xi hung the key of high scholarship on his vest. In 1915 he started his career in the United States Forest Service as an assistant ranger on the Santa Fe National Forest. Here he first encountered his life-problem: the abuse of the range by too many livestock. No locality in the West provides a more dramatic example, for some of these lovely mountain meadows and sun-soaked foothills have been over-sheeped and over-cowed since DeVargas unfurled the Spanish flag on the Santa Fe Plaza in 1610.

By the time I first met Cooperrider (about 1920) he was already one of the recognized technical thinkers of the branch of grazing for the Southwest, and had already demonstrated his ability not only to criticize the stockman as a land-user, but to understand and sympathize with him as a human being.

In 1932 Cooperrider established and assumed charge of the Sierra Ancha Experimental Forest at Parker Creek, in the Tonto Basin of Arizona. Here he made physical measurements of streamflow and plant growth as related to various intensities of grazing, and of soil moving seaward at various resultant rates.

To create and apply a technology of range conservation to the Tonto Basin was—and still is—a formidable task. It embraces three altitudinal zones, each with its distinctive flora and fauna. All three had been overgrazed since the 1880's by a system of competitive cattle ranches. Many of the herds could not be counted because they occupied the range yearlong, and because they were screened from human view by interminable brushfields. Their owners led a dual life: to their bankers they magnified their holdings to bolster credit, and to the Forest Service they minimized them to escape reductions. The cattlemen tended, quite naturally, to stock their ranges to what they could carry in a wet year; the Forest Service, as the custodian of the watershed tended to reduce livestock to what the ranges could carry in a dry year. The problem was further complicated by the fact that overstocked ranges often produced fat cattle, especially in a wet year, by reason of the heavy growth of annuals. In addition to these confusing aspects of cattle grazing, the sheep of the Arizona

desert move north across the tonto each spring to the high mountain meadows of the Coconino Plateau, and back again in the fall.

For years the Tonto ranges had taken the brunt of such devil-take-the-hindmost exploitations. Cooperrider's job was to demonstrate, at Parker Creek, how an orderly and conservative system of range management might be applied, and why its application was imperative. This he did, and in doing so, made many friends among the quarreling groups whose grazing privileges were curtailed by his research findings.

The soil that moves seaward from the incredibly jagged topography of the Sierra Anchas is destined never to reach the sea, for it lodges in the Roosevelt Reservoir, which waters the irrigated farms of the Salt River Valley. Every new acre-foot of soil spewed into the reservoir reduces, by just that much, its capacity to store water. Cooperrider's constantly repeated message to the people of Arizona was that enough capacity had already been lost to threaten the future of the valley farms. Their response, or rather the response of some of them, is the saddest instance of ecological blindness and deafness so far coming to my notice. This response was that conserving range plants to hold soil meant feeding the plants a part of the water needed for irrigation, and that Salt River wanted more water now, regardless of future storage. In short, what has posterity done for us?

It is no small feat to live with such people, to like them, and to hope for their ultimate awakening.

* * *

It was during his Parker Creek days that I first became aware of the wide diversity of Cooperrider's intellectual life. He knew the history, as well as the current dilemmas, of the Southwest. He had a deeper grasp of wildlife than most wildlifers had. Silviculture was within the orbit of his mind, especially the problem of getting ponderosa pine to reproduce in grazed forests. Among other things he promulgated the idea, since proved correct, that lighter grazing during spring and fall drouths would enable newborn pine seedlings to survive livestock. Only those who realize how many throws of the reproductive dice must fail before one succeeds in starting a new generation of pines can understand the difficulty of this problem.

In 1937 Cooperrider took charge of flood control surveys for the Forest Service, applying to the Gila and Rio Grande the principles he had worked out for the Salt River at the Sierra Ancha Station. His reports on these watersheds are listed in the bibliography.

Each of these surveys had, perforce, to deal with a professional cleavage of long standing, as between foresters and engineers. In my opinion one reason for this cleavage was that many foresters, in the early days, had been thinking too narrowly; they knew too little about grass, brush, and cattle, and they failed to appreciate fully that hydrology, as well as forestry, had been making headway. Likewise many engineers were thinking too narrowly; they lacked the concept of interdependence between water, soil, plants and animals. One of Cooperrider's services to conservation was to strive for a synthesis of these diverging viewpoints. In the end he had the respect and confidence, if not the full agreement, of the leading thinkers in forest ecology, range ecology, and watershed engineering in the Southwest.

* * *

The published papers bearing Cooperrider's signature by no means span the wide bracket within which he worked, nor do they record all of the important data he had collected. This disparity between performance and print is almost inevitable when a research man pioneers a new field under heavy and often hostile economic pressure. I cannot remember Charles Cooperrider ever sitting down to a month's uninterrupted writing; he was forever in demand to go and explain this, go and start that, or go and pacify so-and-so.

Perhaps this same continuity of interruptions likewise explains why Cooperrider's pen seldom carried as much force as his personality. The pioneering thoughts and facts are in his publications for people to use if they know what is good for them, but the style hardly does justice to Cooperrider's personal warmth and color. A list of his principal publications is appended to this paper.

During World War II Cooperrider's deep knowledge of plants brought about his assignment to Mexico on the Guayule rubber project. There his health, never any too good, suffered an impairment which finally resulted in his death, at the Baltimore Marine Hospital, on July 13, 1944, at the age of 55. His wife, the late Effie Hedges Cooperrider, had died in 1936. Two of their children survive: Bill Knesal, now a forestry student at Colorado A & M College, and Nancy Hedges, now a student at the University of Arizona.

To appraise justly the value of a career like "Coop's" is a difficult task for a friend, but to remember vividly the warmth and kindliness of his personality is no task at all. To me, and to a hundred others, he was, and will always remain, an ever-smiling guide and pioneer on that steep hard trail toward conservation which still leads up and up.

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The assistance of Bernard Hendricks, Raymond Price, and M. W. Talbot in gathering these materials is gratefully acknowledged.—ALDO LEOPOLD.

ROBERT GLADDING GREEN

1895–1947

Dr. Robert G. Green, Professor and head of the Department of Bacteriology and Immunology of the University of Minnesota School of Medicine died suddenly September 6, 1947. He was recognized as an outstanding contributor to scientific knowledge in the fields of human and veterinary medicine and wild life research.

Following a boyhood spent in the little-settled territory of northern Minnesota (born Ladena, January 11, 1895), Green pursued his higher education at the University of Minnesota, being graduated with an M.D. degree in 1922.

While a student in Medical School, he was recognized by his professor of bacteriology, Dr. W. P. Larson, as a young man of exceptional scientific promise. In later years, Dr. Green frequently paid fond tribute to Dr. Larson for his guiding influence and wise counsel.

In 1917 Dr. Green married Beryl Sparks. Mrs. Green participated actively in the studies of diseases of wild life and of fur animals and made major contributions to these programs.

Dr. Green's principal fields of scientific interest were diseases of wild animals, and filterable virus diseases of man and animals.

About 1926 he organized an elaborate

program of investigation on the subject of the population cycles of wild animals. From the information available at that time, it appeared that tularemia might be the cause of the periodic decimation of cylic species of mammals and birds. In the "Lake Alexander Investigations," as this program was called, a large amount of information on the natural history of tularemia was obtained. Most of this is still unpublished.

The cause of the "die-off" of snowshoe hares was shown to be not tularemia but a previously undescribed malady characterized in its final stages by convulsions due to a lowered blood sugar. This condition, was named "shock disease"; the cause remains undiscovered.

A second major program of investigation conducted by Dr. Green was concerned with diseases of fur-bearing animals in captivity. He and his associates described two new diseases, both of major economic importance in the fur industry. Fox encephalitis, a virus disease, has been brought under virtual control through the studies of Dr. Green. The second disease, "Chastek paralysis," was found to represent a basically new mechanism of disease production. A vitamin (thiamin) was found to be destroyed by a specific enzyme present in carp and other fish. As a result, on fox ranches when certain kinds of fish were added to a nutritionally adequate diet, extensive losses occurred. Control of this disease is also readily accomplished through knowledge gained in studies carried on in Dr. Green's laboratories.

Canine distemper is a third disease of fur bearing animals that Dr. Green studied extensively. The increased knowledge of this disease and of methods of preventing the infection that have come from Dr. Green's work constitute one of his major scientific achievements.

Probably the most significant contribution made by Dr. Green to the fields of biology and medicine was his advocacy of a theory of the nature of viruses. He early reached the conclusion that viruses were probably derived from free-living microorganisms by a process of retrograde evolution Applying the well known concept that in the evolutionary process, structures that are no longer functionally necessary, tend to disappear; Dr. Green visualized the intracellular environment, in which filterable viruses grow, as providing enzyme systems and other structures that permitted the parasite to lose much of the structure that is essential to the life of organisms less favorably located. This concept has found increasing support during the past decade.

The record of scientific accomplishment by Dr. Green includes discovering and elucidating three entirely new diseases, each of major importance in its field; and making major contributions to the understanding of the nature of filterable viruses. This is clear evidence of a life of unusually fruitful research. With these accomplishments behind him, Dr. Green, at the time of his death, was in the midst of intensive programs of research in the fields of cancer and poliomyelitis. He had recently been appointed to succeed his beloved friend and counselor the late Dr. W. P. Larson, as head of the Department of Bacteriology at the University of Minnesota.

Dr. Green's death, coming as it did, at the very peak of his scientific career has left his colleagues at the University of Minnesota and his many friends and associates with a sense of great personal loss and a feeling that his passing constitutes a major set-back for the fields of biology and medicine in which he was interested.

—CHARLES A. EVANS.

ALDO LEOPOLD
1886–1948